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CLASS 1 MODIFICATIONS TO HANFORD FACILITY RCRA PERMIT

SECTION 2 OF 7

- Update of receptor locations based on land use or land-use zoning changes, if any

If the risk goals are exceeded in the PRA or the FRA additional site specific data will be evaluated for use in the assessments, subject to Ecology approval.

7.7 References

7.7.1 Project Documents

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Table 7-1 Human Receptor Populations and Exposure Pathways for the PRA for the Hanford WTP

		Exposure Pathways																	
		Inhalation Routes			External Radiation		Ingestion											Absorp-tion	
Receptor	**Location**	Emissions[a]	Resuspended Soil	Sweat Lodge Vapors[b]	Radionuclides in air	Radionuclides in soil	Soil	Produce	Beef	Milk	Chicken & Eggs	Pork	Wild Produce	Wild Game	Wildfowl & Eggs	Fish[b]	Drinking Water[b]	Sweat Lodge Vapors[b]	Breast milk[c]
Plausible Exposure Scenarios (evaluated in current and future timeframes)																			
Hanford site industrial worker (adult)	Works at onsite ground maximum	X	X		X	X	X												
	Resides at Hanford offsite location	X	X		X	X	X												X
	Consumes homegrown produce (offsite)							X											
	Consumes water (Columbia River max)																X		
Resident (adult and child)	Resides at Hanford offsite location	X	X		X	X	X												
	Consumes homegrown produce (offsite)							X											X
	Consumes water (Columbia River max)																X		
Resident Subsistence American Indian (adult and child)	Resides at Hanford offsite location	X	X		X	X	X												
	Consumes wild produce/game (hunter/gatherer area)												X	X	X	X			X
	Consumes water (Columbia River max)			X													X	X	
Worst-Case Exposure Scenario (evaluated in current and future timeframes)																			
Resident subsistence farmer (adult and child)	Resides at Hanford offsite location	X	X		X	X	X												
	Consumes homegrown produce/livestock (offsite)							X	X	X	X	X							X
	Consumes water (Columbia River max)																X		
Resident subsistence fisher (adult and child)	Resides at Hanford offsite location	X	X		X	X	X												
	Consumes homegrown produce (offsite)							X											X
	Consumes fish and water (Columbia River max)															X	X		
Acute exposure	Acute maximum	X			X														

Table 7-1 Human Receptor Populations and Exposure Pathways for the PRA for the Hanford WTP

		Exposure Pathways																	
		Inhalation Routes			External Radiation		Ingestion											Absorp-tion	
Receptor	Location	Emissions[a]	Resuspended Soil	Sweat Lodge Vapors[b]	Radionuclides in air	Radionuclides in soil	Soil	Produce	Beef	Milk	Chicken & Eggs	Pork	Wild Produce	Wild Game	Wildfowl & Eggs	Fish[b]	Drinking Water[b]	Sweat Lodge Vapors[b]	Breast milk[c]
Alternate Exposure Scenarios (evaluated in current and future timeframes)																			
Alternate Resident subsistence American Indian, scenario #1 (adult and child)	Resides at Hanford offsite location	X	X		X	X	X												X
	Visits Gable Mountain maximum	X	X		X	X	X												
	Consumes wild produce/game (hunter/gatherer area)												X	X	X	X			
	Consumes fish and water (Columbia River max)			X													X	X	
Alternate Resident subsistence American Indian, scenario #2 (adult and child)	Resides at Hanford offsite location	X	X		X	X	X												X
	Consumes homegrown produce/livestock (offsite)							X	X	X	X	X							
	Consumes wild produce/game (hunter/gatherer area)												X	X	X	X			
	Consumes fish and water (Columbia River max)			X													X	X	
	Consumes water (Columbia River max)			X													X	X	

X = complete exposure pathway for receptor.

[a] Includes direct inhalation of vapor phase and particulate emissions. Applicable to current timeframe only (during WTP emissions).

[b] Pathway attributable to exposure to water/fish from the Columbia River maximum. Applicable to current timeframe only (during WTP emissions); subsequent to WTP operation, deposited constituents are transported down river.

[c] Includes nursing infant assessment - maternal exposures indicated.

Table 7-2 Hanford Site Industrial Worker Exposure Parameters

Parameter	Description	Units	Onsite Worker	Source or Reference
EF	Exposure frequency	days/yr	350	CCN 064331, EPA to WTP Regarding Human Exposure Scenarios and Exposure Parameters, Personal communication between SAIC and US Environmental Protection Agency, Region 10, at a meeting held on 8 and 9 October 2002 in Seattle, Washington, USA.
EF_{work}	Exposure frequency at work	days/yr	250	CCN 063816, EPA to WTP Regarding Exposure Durations for Worker, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 19 December 2002.
EF_{retire}	Exposure frequency during retirement	days/yr	350	HHRAP Table C-1-8
ED	Exposure duration	yr	20	CCN 063816, EPA to WTP Regarding Exposure Durations for Worker, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 19 December 2002.
ED_{work}	Exposure duration at work	yr	20	
ED_{retire}	Exposure duration during retirement	yr	10	
ET	Exposure time	hr/day	24	CCN 063807, EPA to WTP Regarding Exposure Scenarios and Exposure, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 13 June 2002.
ET_{work}	Exposure time at work	hr/day	8	
BW	Body weight	kg	70	HHRAP Appendix C
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	20	CCN 063816, EPA to WTP Regarding Exposure Durations for Worker, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 19 December 2002.
AT_N	Averaging time for noncarcinogens	yr	20	
$AT_{N\ retire}$	Averaging time for noncarcinogens during retirement	yr	10	

Table 7-2 Hanford Site Industrial Worker Exposure Parameters

Parameter	Description	Units	Onsite Worker	Source or Reference
IR	Inhalation rate	m^3/hr	0.833	CCN 063805, EPA to WTP Regarding Exposure Parameters, E-mail communication from Cathy Massimino, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 4 September 2002.
IR_{work}	Inhalation rate at work	m^3/hr	1.5	
CR_{soil}	Ingestion rate for soil	kg/day	0.0001	CCN 064331, EPA to WTP Regarding Human Exposure Scenarios and Exposure Parameters, Personal communication between SAIC and US Environmental Protection Agency, Region 10, at a meeting held on 8 and 9 October 2002 in Seattle, Washington, USA.
$CR_{soil\ work}$	Ingestion rate for soil at work	kg/day	0.0002	
CR_{dw}	Ingestion rate for drinking water	L/day	2	CCN 063813, EPA to WTP Regarding Drinking Water Ingestion Rate for Worker, E-mail communication from Marcia Bailey, US Environmental Protection Agency EPA Region 10 to Sharon Robers, SAIC, 10 January 2003.
$CR_{dw\ offwork}$	Ingestion rate for drinking water after work	L/day	1	
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	0.00032	HHRAP Table C-1-2 (Resident)
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	0.00014	
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	0.00061	

Table 7-2 Hanford Site Industrial Worker Exposure Parameters

Parameter	Description	Units	Onsite Worker	Source or Reference
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil (non-work days)	unitless	0.060	EPA. 1997. Exposure Factors Handbook, EPA/600/P-95/002Fa. Office of Research and Development, US Environmental Protection Agency, Washington, DC, USA. (for after-workday exposures, the exposure time factor for indoor exposure is adjusted for the 8 hrs spent at work [0.607 = 0.94 - 8/24])
ET_i	Exposure time factor for indoor exposure to ROPCs in soil (non-work days)	unitless	0.940	
$ET_{o\ offwork}$	Exposure time factor for outdoor exposure to ROPCs in soil after work	unitless	0.060	
$ET_{i\ offwork}$	Exposure time factor for indoor exposure to ROPCs in soil after work	unitless	0.607	
$ET_{o\ work}$	Exposure time factor for outdoor exposure to ROPCs in soil at work	unitless	0.167	Exposure is for 4 hr/day indoor, and 4 hr/day outdoor while at work. See RAWP Section 7.1.6.1.
$ET_{i\ work}$	Exposure time factor for indoor exposure to ROPCs in soil at work	unitless	0.167	
Nursing Infant Exposure Parameters				
ED_{infant}	Exposure duration	yrs	1	HHRAP Table C-3-2
$ED_{maternal}$	Maternal exposure duration	yr	20	CCN 063816, EPA to WTP Regarding Exposure Durations for Worker, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 19 December 2002.
IR_{milk}	Ingestion rate: breast milk	L/day	0.688	HHRAP Table C-3-2

Table 7-2 Hanford Site Industrial Worker Exposure Parameters

Parameter	Description	Units	Onsite Worker	Source or Reference
BW_{infant}	Body weight	kg	7.2	CCN 063806, EPA to WTP Regarding Infant Body Weight, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 31 October 2002 (2:26 p.m.).
AT_{infant}	Averaging time for carcinogens	yr	1	HHRAP Table C-3-2

HHRAP: EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, EPA/530/R-05/006, US Environmental Protection Agency, Washington, DC. (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm).

Table 7-3 Resident Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
EF	Exposure frequency	days/yr	350	350	HHRAP Tables C-1-7 and C-1-8
ED	Exposure duration	yr	30	6	HHRAP Tables C-1-7 and C-1-8
ET	Exposure time	hr/day	24	24	Assumed (conservative) value
BW	Body weight	kg	70	15	HHRAP Appendix C
AT_C	Averaging time for carcinogens	yr	70	70	HHRAP Table C-1-7
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	30	6	HHRAP Table C-1-8
AT_N	Averaging time for noncarcinogens	yr	30	6	
IR	Inhalation rate	m^3/hr	0.833	0.417	CCN 063805, EPA to WTP Regarding Exposure Parameters, E-mail communication from Cathy Massimino, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 4 September 2002.
CR_{soil}	Ingestion rate for soil	kg/day	0.0001	0.0002	HHRAP Table C-1-1
CR_{dw}	Ingestion rate for drinking water	L/day	2	1	CCN 063807, EPA to WTP Regarding Exposure Scenarios and Exposure, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 13 June 2002.
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	0.00032	0.00077	HHRAP Table C-1-2
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	0.00014	0.00023	
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	0.00061	0.0015	
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil	unitless	0.06	0.23	EPA. 1997. Exposure Factors Handbook, EPA/600/P-95/002Fa. Office of Research and Development, US Environmental Protection Agency,

Table 7-3 Resident Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
ET_i	Exposure time factor for indoor exposure to ROPCs in soil	unitless	0.94	0.77	Washington, DC, USA.(Table 15-176; 1.5 hr/day outdoor occupancy [adult], 5.6 hr/day (wt. ave.) outdoor occupancy [child])
Nursing Infant Exposure Parameters					
ED_{infant}	Exposure duration	yr	na	1	HHRAP Table C-3-2
$ED_{maternal}$	Maternal exposure duration	yr	30	na	HHRAP Table C-3-1
IR_{milk}	Ingestion rate: breast milk	L/day	na	0.688	HHRAP Table C-3-2
BW_{infant}	Body weight	kg	na	7.2	CCN 063806, EPA to WTP Regarding Infant Body Weight, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 31 October 2002 (2:26 p.m.).
AT_{infant}	Averaging time for carcinogens	yr	na	1	HHRAP Table C-3-2

na = not applicable

HHRAP: EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, EPA/530/R-05/006, US Environmental Protection Agency, Washington, DC. (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm).

Table 7-4 Resident Subsistence Farmer Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
EF	Exposure frequency	days/yr	350	350	HHRAP Tables C-1-7 and C-1-8
ED	Exposure duration	yr	40	6	HHRAP Tables C-1-7 and C-1-8
ET	Exposure time	hr/day	24	24	Assumed (conservative) value
BW	Body weight	kg	70	15	HHRAP Appendix C
AT_C	Averaging time for carcinogens	yr	70	70	HHRAP Table C-1-7
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	40	6	HHRAP Table C-1-8
AT_N	Averaging time for noncarcinogens	yr	40	6	
IR	Inhalation rate	m^3/hr	0.833	0.417	CCN 063805, EPA to WTP Regarding Exposure Parameters, E-mail communication from Cathy Massimino, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 4 September 2002.
CR_{soil}	Ingestion rate for soil	kg/day	0.0001	0.0002	HHRAP Table C-1-1
CR_{dw}	Ingestion rate for drinking water	L/day	2	1	CCN 063807, EPA to WTP Regarding Exposure Scenarios and Exposure, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 13 June 2002.
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	0.00047	0.00113	HHRAP Table C-1-2
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	0.00017	0.00028	
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	0.00064	0.00157	
$CR_{domestic\ fowl}$	Consumption rate domestic chicken	kg/kg-day FW	0.00066	0.00045	HHRAP Table C-1-3
CR_{beef}	Consumption rate: beef	kg/kg-day FW	0.00122	0.00075	HHRAP Table C-1-3
CR_{pork}	Consumption rate: pork	kg/kg-day FW	0.00055	0.00042	
CR_{eggs}	Consumption rate: eggs	kg/kg-day FW	0.00075	0.00054	

Table 7-4 Resident Subsistence Farmer Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
CR_{milk}	Consumption rate: milk	kg/kg-day FW	0.01367	0.02268	HHRAP Table C-1-3
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil	unitless	0.42	0.42	EPA. 1997. Exposure Factors Handbook, EPA/600/P-95/002Fa. Office of Research and Development, US Environmental Protection Agency, Washington, DC, USA.(Table 15-112, 90th percentile for all, 600 minutes outdoor occupancy)
ET_i	Exposure time factor for indoor exposure to ROPCs in soil	unitless	0.58	0.58	
Nursing Infant Exposure Parameters					
ED_{infant}	Exposure duration	yr	na	1	HHRAP Table C-3-2
$ED_{maternal}$	Maternal exposure duration	yr	40	na	HHRAP Table C-3-1
IR_{milk}	Ingestion rate: breast milk	L/day	na	0.688	HHRAP Table C-3-2
BW_{infant}	Body weight	kg	na	7.2	CCN 063806, EPA to WTP Regarding Infant Body Weight, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 31 October 2002 (2:26 p.m.).
AT_{infant}	Averaging time for carcinogens	yr	na	1	HHRAP Table C-3-2

na = not applicable

HHRAP: EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, EPA/530/R-05/006, US Environmental Protection Agency, Washington, DC. (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm).

Table 7-5 Resident Subsistence Fisher Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
EF	Exposure frequency	days/yr	350	350	HHRAP Tables C-1-7 and C-1-8
ED	Exposure duration	yrs	30	6	HHRAP Tables C-1-7 and C-1-8
ET	Exposure time	hr/day	24	24	Assumed (conservative) value
BW	Body weight	kg	70	15	HHRAP Appendix C
AT_C	Averaging time for carcinogens	yr	70	70	HHRAP Table C-1-7
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	30	6	HHRAP Table C-1-8
AT_N	Averaging time for noncarcinogens	yr	30	6	
IR	Inhalation rate	m^3/hr	0.833	0.417	CCN 063805, EPA to WTP Regarding Exposure Parameters, E-mail communication from Cathy Massimino, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 4 September 2002.
CR_{soil}	Ingestion rate for soil	kg/day	0.0001	0.0002	HHRAP Table C-1-1
CR_{dw}	Ingestion rate for drinking water	L/day	2	1	CCN 063807, EPA to WTP Regarding Exposure Scenarios and Exposure, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 13 June 2002.
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	0.00032	0.00077	HHRAP Table C-1-2
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	0.00014	0.00023	
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	0.00061	0.0015	
CR_{fish}	Consumption rate: fish	kg/kg-day FW	0.00125	0.00088	HHRAP Table C-1-4

Table 7-5 Resident Subsistence Fisher Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil	unitless	0.42	0.42	EPA. 1997. Exposure Factors Handbook, EPA/600/P-95/002Fa. Office of Research and Development, US Environmental Protection Agency, Washington, DC, USA.(Table 15-112, 90th percentile for all, 600 minutes outdoor occupancy)
ET_i	Exposure time factor for indoor exposure to ROPCs in soil	unitless	0.58	0.58	
Nursing Infant Exposure Parameters					
ED_{infant}	Exposure duration	yr	na	1	HHRAP Table C-3-2
$ED_{maternal}$	Maternal exposure duration	yr	30	na	HHRAP Table C-3-1
IR_{milk}	Ingestion rate: breast milk	L/day	na	0.688	HHRAP Table C-3-2
BW_{infant}	Body weight	kg	na	7.2	CCN 063806, EPA to WTP Regarding Infant Body Weight, E-mail communication from Marcia Bailey, US Environmental Protection Agency Region 10, to Sharon Robers, SAIC, 31 October 2002 (2:26 p.m.).
AT_{infant}	Averaging time for carcinogens	yr	na	1	HHRAP Table C-3-2

na = not applicable

HHRAP: EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, EPA/530/R-05/006, US Environmental Protection Agency, Washington, DC. (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm).

Table 7-6 DOE Resident Subsistence American Indian Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
EF	Exposure frequency	days/yr	365	365	Appendix D (p. D-296) of EIS-0189 ("continuous occupancy")
ED	Exposure duration	yr	70	6	For adults, the equation for HQsn on p. Q-14 of EIS-0391: Averaging Time (25,550 days). Per the HHRAP, a exposure duration of 6 yrs is assumed for children.
ET	Exposure time	hr/day	24	24	Appendix D (p. D-296) of EIS-0189 ("continuous occupancy")
ET_{sw}	Exposure time for sweat lodge	hr/day	2	2	Table Q-14 of EIS-0391
BW	Body weight	kg	70	16	Table D.2.1.3 of EIS-0189
AT_C	Averaging time for carcinogens	yr	70	70	Eqn for HQsn on p. Q-14 of EIS-0391: Averaging Time
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	40	6	Duration of WTP operation; 40 yr duration applies to adult inhalation and water exposures (including fish consumption), 70 yr duration applies to adult soil and ingestion (excluding fish) related exposures. Child averaging time is limited to 6 yrs. See exposure duration source/reference.
IR	Inhalation rate	m^3/hr	0.959	0.625	Table Q-9 of EIS-0391 (adult); Table D.2.1.3 of EIS-0189 (child)
CR_{soil}	Ingestion rate for soil	kg/day	0.0001	0.0002	Table Q-10 of EIS-0391 (adult); Table D.2.1.3 of EIS-0189 (child). The value in Table Q-10 is a weighted average for the adult and child. Backing out the child consumption rate in EIS-0189 yields and adult consumption rate of approximately 100 mg/day.
CR_{dw}	Ingestion rate for drinking water	L/day	4	1.5	Table J-23 of EIS-0391 (adult); Table D.2.1.3 of EIS-0189 (child)

Table 7-6 DOE Resident Subsistence American Indian Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
$CR_{ag\ wild}$	Consumption rate: aboveground wild produce	kg/kg-day FW	0.0025	0.0038	Table J-23 & Q-10 of EIS-0391: Leafy vegetable consumption rate (adult). For the child, assume a daily mass (vegetable) consumption of 34% of the adult based on comparison of data in CSEFH (weighted average consumption, mean values, ages 3 through 6) and EFH (weighted average consumption, mean values, ages 7 through 70).
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	-	-	No domestic agriculture consumption reported/available.
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	-	-	No belowground agriculture consumption reported/available.
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	0.013	0.027	Table J-23 & Q-10 of EIS-0391: Fruit, vegetable, and grain consumption rate (kg/yr) (adult). For the child, assume a daily mass (fruit) consumption of 48% of the adult based on comparison of data in CSEFH (weighted average consumption, mean values, ages 3 through 6) and EFH (weighted average consumption, mean values, ages 7 through 70).
CR_{fowl}	Consumption rate wild fowl	kg/kg-day FW	-	-	No wild fowl consumption reported/available.
$CR_{domestic\ fowl}$	Consumption rate domestic chicken	kg/kg-day FW	-	-	No domestic fowl consumption reported/available.
CR_{game}	Consumption rate: wild game	kg/kg-day FW	0.0060	0.013	Table Q-10 of EIS-0391: Meat and poultry consumption (only a deer exposure equation is provided in App. Q so its assumed the rate provided here is just for game) (adult). For the child, assume a daily mass (beef) consumption of 48% of the adult based on comparison of data in CSEFH (weighted average consumption, mean values, ages 3 through 6) and EFH (weighted average consumption, mean values, ages 7 through 70).
$CR_{game\ organs}$	Consumption rate: game organs	kg/kg-day FW	-	-	No organ consumption reported/available.

Table 7-6 DOE Resident Subsistence American Indian Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
CR_{beef}	Consumption rate: beef	kg/kg-day FW	-	-	No domestic livestock consumption reported/available.
CR_{pork}	Consumption rate: pork	kg/kg-day FW	-	-	No domestic livestock consumption reported/available.
CR_{eggs}	Consumption rate: eggs	kg/kg-day FW	0.00074	0.0022	Table J-23 of EIS-0391 (adult).For the child, assume a daily mass (eggs) consumption of 67% of the adult based on comparison of data in CSEFH (weighted average consumption, mean values, ages 3 through 6) and EFH (weighted average consumption, mean values, ages 7 through 70).
CR_{fish}	Consumption rate: fish	kg/kg-day FW	0.0088	0.0101	Table J-23 and Q.2.4.2, 3rd para. of EIS-0391 (adult). For the child, assume a daily mass (total fish) consumption of 26% of the adult based on comparison of data in CSEFH (weighted average consumption, mean values, ages 3 through 6) and EFH (weighted average consumption, mean values, ages 7 through 70).
$CR_{fish\ organs}$	Consumption rate: fish organs	kg/kg-day FW	-	-	No organ consumption reported/available.
CR_{milk}	Consumption rate: milk	kg/kg-day FW	0	0	Table Q-3 of EIS-0391
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil	unitless	0.12	0.12	Table Q-5 of EIS-0391 (note: the EIS assumes that for a portion of the time the receptor was not present at the location.)
ET_i	Exposure time factor for indoor exposure to ROPCs in soil	unitless	0.66	0.66	Table Q-5 of EIS-0391
SA	Dermal Surface Area	m^2	1.8	0.76	EFH Tables 6-2 and 6-3, average of male & female 50th percentile dermal surface areas (adults). CSEFH, Table 7-1, mean total body skin surface area of a 3 to <6 yr. old (for child).
V_w	Volume of Water used in Sweat Lodge	L	4	4	Harper & Harris 1997

Table 7-6 DOE Resident Subsistence American Indian Exposure Parameters

Parameter	Description	Units	Adult	Child	Source or Reference
D	Diameter of Sweat Lodge	m	2	2	Harper & Harris 1997
T_{sl}	Temperature of Sweat Lodge	°F	122	122	Table Q-15 of EIS-0391
Nursing Infant Exposure Parameters					
ED_{infant}	Exposure duration	yrs	na	1	Based on CSEFH, Table 15-12, mean value rounded to the nearest whole year.
$ED_{maternal}$	Maternal exposure duration	yrs	25	na	Assume the same as in Harris 2004. Section 2.2.3, page 15
IR_{milk}	Ingestion rate: breast milk	L/day	na	0.62	CSEFH, Table 15-1, mean for infants 6-12 mos.
BW_{infant}	Body weight	kg	na	9.2	Based on CSEFH, Table 8-1, mean of 6 to <11 month old infant.
AT_{infant}	Averaging time for carcinogens	yrs	na	1	Set to exposure duration.

na = not applicable

CSEFH: EPA. 2008. *Child-Specific Exposure Factors Handbook*, EPA/600/R-06/096F, National Center for Environmental Assessment, Office of Research and Development, Washington DC, September 2008.

EIS-0391: US Department of Energy. 2012. *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site*, DOE/EIS-0391, Richland, Washington, November.

EIS-0189: US Department of Energy. 1996. *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, DOE/EIS-0189, August.

EFH: EPA. 1997. *Exposure Factors Handbook, Final*, EPA/600/P-95/002F, US Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC, August 1997.

Table 7-7 Alternate Resident Subsistence American Indian Scenario #1

Parameter	Description	Units	Adult	Child	Source or Reference
EF	Exposure frequency	days/yr	365	365	Harris 2004.
$EF_{ceremony}$	Exposure frequency during tribal ceremonies	days/yr	12	12	Assumed value (1 day/mon. for ceremonial activities, see RAWP)
ED	Exposure duration	yr	70	6	Harris 2008.
ET	Exposure time	hr/day	24	24	Harris 2004.
ET_{sw}	Exposure time for sweat lodge	hr/day	1	1	Harris 2004.
BW	Body weight	kg	70	15	Harris 2004 (adult) and HHRAP 2005 (child).
AT_C	Averaging time for carcinogens	yr	70	70	Harris 2008.
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	40	6	Harris 2008. 40 yr duration applies to inhalation and water exposures (including fish consumption), 70 yr duration applies to soil and ingestion (excluding fish) related exposures.
AT_N	Averaging time for noncarcinogens	yr	70	6	
IR	Inhalation rate	m^3/hr	1.04	0.625	Harris 2008.
CR_{soil}	Ingestion rate for soil	kg/day	0.0004	0.0004	Harris 2008.
CR_{dw}	Ingestion rate for drinking water	L/day	4	2	Harris 2008 (adults only). Child consuption rate assumed half of the adult's (see Rudolfi 2007).
$CR_{ag\ wild}$	Consumption rate: aboveground wild produce	kg/kg-day FW	0.0048	0.016	Harris 2008 (adults only). Based on 337 g/day of berries, fruits, other vegetation, greens, tea, medicines, spices, honey, sweeteners, seeds, nuts, and grains. Children's exposure factors are based on CSEFH, 1466 kcal/d diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	-	-	No domestic agriculture consumption reported/available.

Table 7-7 Alternate Resident Subsistence American Indian Scenario #1

Parameter	Description	Units	Adult	Child	Source or Reference
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	0.0063	0.021	Harris 2008 (adults only). Based on 440 g/day of bulbs, tubers, and roots. Children's exposure factors are based on CSEFH, 1466 kcal/d diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	-	-	Specific protected produce values are not reported; it is assumed aboveground consumption rates include protected produce.
CR_{fowl}	Consumption rate wild fowl	kg/kg-day FW	0.00089	0.0029	Harris 2008 (for adults). Children's exposure factors are based on CSEFH, 1466 kcal/day diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
$CR_{domestic\ fowl}$	Consumption rate domestic chicken	kg/kg-day FW	-	-	No domestic fowl consumption reported/available.
CR_{game}	Consumption rate: wild game	kg/kg-day FW	0.0016	0.0050	Harris 2008 (adults only). Per Harris 2008, organ consumption accounts for 10% of the total game consumed, thus, 90% is attributed to game meat. Children's exposure factors are based on CSEFH, 1466 kcal/d diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
$CR_{game\ organs}$	Consumption rate: game organs	kg/kg-day FW	0.00018	0.00056	Harris 2008 (adults only). Per Harris 2008, organ consumption accounts for 10% of the total game consumed. Children's exposure factors are based on CSEFH, 1466 kcal/d diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
CR_{beef}	Consumption rate: beef	kg/kg-day FW	-	-	No domestic livestock consumption reported/available.
CR_{pork}	Consumption rate: pork	kg/kg-day FW	-	-	No domestic livestock consumption reported/available.
CR_{eggs}	Consumption rate: eggs	kg/kg-day FW	-	-	Provided in the fowl consumption rate (Harris 2008). Proportion of diet is not stated.

Table 7-7 Alternate Resident Subsistence American Indian Scenario #1

Parameter	Description	Units	Adult	Child	Source or Reference
CR_{fish}	Consumption rate: fish	kg/kg-day FW	0.0080	0.025	Harris 2008 (adults only). Per Harris 2008, organ consumption accounts for 10% of the total fish consumed. Children's exposure factors are based on CSEFH, 1466 kcal/d diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
$CR_{fish\ organs}$	Consumption rate: fish organs	kg/kg-day FW	0.00089	0.0027	Harris 2008 (adults only).Per Harris 2008, organ consumption accounts for 10% of the total fish consumed. Children's exposure factors are based on CSEFH, 1466 kcal/d diet for a 3-5 yr old, shown in Table 6-35, but scaled from the adult (see Harris 2004, Section 2.3.1).
CR_{milk}	Consumption rate: milk	kg/kg-day FW	-	-	No milk consumption reported/available.
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil	unitless	0.5	0.5	Harris 2008.
ET_i	Exposure time factor for indoor exposure to ROPCs in soil	unitless	0.5	0.5	Harris 2008.
SA	Dermal Surface Area	m^2	1.8	0.76	Harris 2008, Appendix A, Table 3 (adults only). CSEFH, Table 7-1, mean total body skin surface area of a 3 to <6 yr. old (for child).
V_w	Volume of Water used in Sweat Lodge	L	4	4	Harper & Harris 1997
D	Diameter of Sweat Lodge	m	2	2	Harper & Harris 1997
T_{sl}	Temperature of Sweat Lodge	°F	150	150	Harper & Harris 1997
Nursing Infant Exposure Parameters					
ED_{infant}	Exposure duration	yr	na	2	Harris 2004. Section 2.2.3, page 15
$ED_{maternal}$	Maternal exposure duration	yr	25	na	Harris 2004. Section 2.2.3, page 15
IR_{milk}	Ingestion rate: breast milk	L/day	na	0.742	Harper & Harris 1997

Table 7-7 Alternate Resident Subsistence American Indian Scenario #1

Parameter	Description	Units	Adult	Child	Source or Reference
BW_{infant}	Body weight	kg	na	9.2	Based on CSEFH, Table 8-1, mean of 6 to <11 month old infant.
AT_{infant}	Averaging time for carcinogens	yrs	na	2	Set to exposure duration.

na = not applicable

CSEFH: EPA. 2008. *Child-Specific Exposure Factors Handbook*, EPA/600/R-06/096F, National Center for Environmental Assessment, Office of Research and Development, Washington DC, September 2008.

EFH: EPA. 1997. *Exposure Factors Handbook, Final*, EPA/600/P-95/002F, US Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC, August 1997.

HHRAP: EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, EPA/530/R-05/006, US Environmental Protection Agency, Washington, DC. (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm).

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Table 7-8 Alternate Resident Subsistence American Indian Scenario #2

Parameter	Description	Units	Adult	Child	Source or Reference
EF	Exposure frequency	days/yr	365	365	RIDOLFI Inc. 2007.
ED	Exposure duration	yr	70	6	RIDOLFI Inc. 2007.
ET	Exposure time	hr/day	24	24	RIDOLFI Inc. 2007.
ET_{sw}	Exposure time for sweat lodge	hr/day	7	0.71	RIDOLFI Inc. 2007. Used recommended value from report which was 7 hour/day for adults, and the average reported (5 hrs/week) for children.
BW	Body weight	kg	70	16	RIDOLFI Inc. 2007.
AT_C	Averaging time for carcinogens	yr	70	70	RIDOLFI Inc. 2007.
$AT_{N\ inhal}$	Inhalation Averaging time for noncarcinogens	yr	40	6	RIDOLFI Inc. 2007. 40 yr duration applies to inhalation and water exposures (including fish consumption), 70 yr duration applies to soil and ingestion (excluding fish) related exposures.
AT_N	Averaging time for noncarcinogens	yr	70	6	
IR	Inhalation rate	m^3/hr	1.08	0.67	RIDOLFI Inc. 2007.
CR_{soil}	Ingestion rate for soil	kg/day	0.0002	0.0004	RIDOLFI Inc. 2007.
CR_{dw}	Ingestion rate for drinking water	L/day	4	2	RIDOLFI Inc. 2007.
$CR_{ag\ wild}$	Consumption rate: aboveground wild produce	kg/kg-day FW	0.0069	0.0067	RIDOLFI Inc. 2007. Table 7 of Ridolfi 2007 provides an adult value of 1118 g/day summed across the categories of wild roots, stalks/leaves, and vegetables plus an additional 299 g/day of fruit for a total of 1417 g/day. The total for children is 314 g/day. Based on Figure 9, the average domestic produce (assume aboveground) consumption constitutes 36% of the produce diet, while average wild aboveground (stalks, leaves, berries) and belowground (roots) produce consumption constitutes 34% and 31% of the produce diet, respectively. The same diet proportions are assumed for adults and children.
CR_{ag}	Consumption rate: aboveground domestic produce	kg/kg-day FW	0.0072	0.0070	
CR_{bg}	Consumption rate: belowground produce	kg/kg-day FW	0.0062	0.0060	

Table 7-8 Alternate Resident Subsistence American Indian Scenario #2

Parameter	Description	Units	Adult	Child	Source or Reference
CR_{pp}	Consumption rate: protected produce	kg/kg-day FW	-	-	Specific protected produce values are not reported; it is assumed aboveground consumption rates include protected produce.
CR_{fowl}	Consumption rate wild fowl	kg/kg-day FW	0.0013	0.0017	RIDOLFI Inc. 2007. Table 7 of Ridolfi 2007 provides a value of 704 g/day for meat consumption (212 g/day for children). Page 20 indicates %60 of meat consumed is domestic. The reference does not indicate the percentage of meat from game/livestock verses wild/domestic fowl. Data from Harris (2008) indicates poultry is 33% of the game & fowl diet for adults. EPA data (EPA/600/R-06/096F, Table 6-35, 1466 kcal/day diet for a 3-5 yr. old) when proportioned between game and fowl according to Harris (2008) and scaled from the adult per Harris (2004), yields a similar value for the proportion of a child's diet that is poultry (~33%). Thus it is assumed that the receptor diet (for game & fowl only) is 33% poultry.
$CR_{domestic\ fowl}$	Consumption rate domestic chicken	kg/kg-day FW	0.0020	0.0026	
CR_{game}	Consumption rate: wild game	kg/kg-day FW	0.0027	0.0036	RIDOLFI Inc. 2007. Table 7 of Ridolfi 2007 provides a value of 704 g/day for meat consumption (212 g/day for children). Page 20 indicates %60 of meat consumed is domestic. Based on the assumptions used for poultry consumption, it is assumed that 67% of meat consumption is game/livestock (beef).
$CR_{game\ organs}$	Consumption rate: game organs	kg/kg-day FW	-	-	No organ consumption reported/available.

Table 7-8 Alternate Resident Subsistence American Indian Scenario #2

Parameter	Description	Units	Adult	Child	Source or Reference
CR_{beef}	Consumption rate: beef	kg/kg-day FW	0.0040	0.0053	RIDOLFI Inc. 2007.Table 7 of Ridolfi 2007 provides a value of 704 g/day for meat consumption (212 g/day for children). Page 20 indicates %60 of meat consumed is domestic. Based on the assumptions used for poultry consumption, it is assumed that 67% of meat consumption is game/livestock (beef).
CR_{pork}	Consumption rate: pork	kg/kg-day FW	-	-	No distinction made for type of livestock so beef consumption is assumed (no pork consumption assumed).
CR_{eggs}	Consumption rate: eggs	kg/kg-day FW	-	-	Included in the fowl consumption rate
CR_{fish}	Consumption rate: fish	kg/kg-day FW	0.0074	0.023	RIDOLFI Inc. 2007. Table 7 of Ridolfi 2007 provides a value of 519 g/day for adult and 363 g/day for child fish consumption.
$CR_{fish\ organs}$	Consumption rate: fish organs	kg/kg-day FW	-	-	No organ consumption reported/available.
CR_{milk}	Consumption rate: milk	kg/kg-day FW	0.017	0.031	RIDOLFI Inc. 2007. Assume the milk is from domestic, comercial sources (Adult: 1.2 L/day / 70 kg = 0.0171 kg/kg-day. Child: 0.5 L/day / 16 kg = 0.0313 kg/kg-day).
ET_o	Exposure time factor for outdoor exposure to ROPCs in soil	unitless	0.29	0.29	RIDOLFI Inc. 2007. Section 3.2.5.1 (assume max of 7 hrs/day)
ET_i	Exposure time factor for indoor exposure to ROPCs in soil	unitless	0.71	0.71	RIDOLFI Inc. 2007. Section 3.2.5.1 states a maximum of 7 hrs/day is out doors, thus the remaining time is assumed to be indoors.
SA	Dermal Surface Area	m^2	1.8	0.76	In the absence of data in RUDOLFI Inc. 2007, use Harris 2008, Appendix A, Table 3 (adults only). CSEFH, Table 7-1, mean total body skin surface area of a 3 to <6 yr. old (for child).

Table 7-8 Alternate Resident Subsistence American Indian Scenario #2

Parameter	Description	Units	Adult	Child	Source or Reference
V_w	Volume of Water used in Sweat Lodge	L	4	4	Harper & Harris 1997
D	Diameter of Sweat Lodge	m	2	2	Harper & Harris 1997
T_{sl}	Temperature of Sweat Lodge	°F	150	150	Harper & Harris 1997
Nursing Infant Exposure Parameters					
ED_{infant}	Exposure duration	yr	na	2	Assume the same as in Harris 2004. Section 2.2.3, page 15.
$ED_{maternal}$	Maternal exposure duration	yr	25	na	Assume the same as in Harris 2004. Section 2.2.3, page 15
IR_{milk}	Ingestion rate: breast milk	L/day	na	0.742	Harper & Harris 1997
BW_{infant}	Body weight	kg	na	9.2	Based on CSEFH, Table 8-1, mean of 6 to <11 month old infant.
AT_{infant}	Averaging time for carcinogens	yr	na	2	Set to exposure duration.

na = not applicable

CSEFH: EPA. 2008. *Child-Specific Exposure Factors Handbook*, EPA/600/R-06/096F, National Center for Environmental Assessment, Office of Research and Development, Washington DC, September 2008.

Harper & Harris 1997: "A Native American Exposure Scenario," Risk Anal., Volume 17, Issue 6, p 789-795.

RIDOLFI Inc. 2007: RIDOLFI Inc. 2007. *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment*, Yakama Nation ERWM Program, September 2007.

Table 7-9 Modeling Parameters for Estimating Exposure Point Concentrations in Biota for Human Consumption

Parameter	Description	Units	Value	Reference
General/Global Biota Parameters				
F_{plant}	Fraction of plant grown on contaminated soil and ingested by the specific animal being modeled - applies to all plant types (produce, forage, silage, grain are possibilities) eaten by the animal being modeled	unitless	1	[1]
Bs	Soil bioavailability factor	unitless	1	[1]
MF	Metabolism factor for Bis(2-ethylhexyl)phthalate	unitless	0.01	[1]
	Metabolism factor for all other constituents	unitless	1	[1]
Beef Parameters				
Qp_{forage}	Quantity of forage eaten by beef cattle per day	kg DW plant/day	8.8	[1]
Qp_{silage}	Quantity of silage eaten by beef cattle per day	kg DW plant/day	2.5	[1]
Qp_{grain}	Quantity of grain eaten by beef cattle per day	kg DW plant/day	0.47	[1]
Qs	Quantity of soil ingested by beef cattle per day	kg/day	0.5	[1]
Ba	Biotransfer factor for beef	day/kg FW tissue	constituent specific	
Dairy Parameters				
Qp_{forage}	Quantity of forage eaten by dairy cattle per day	kg DW plant/day	13.2	[1]
Qp_{silage}	Quantity of silage eaten by dairy cattle per day	kg DW plant/day	4.1	[1]
Qp_{grain}	Quantity of grain eaten by dairy cattle per day	kg DW plant/day	3	[1]
Qs	Quantity of soil eaten by dairy cattle per day	kg/day	0.4	[1]
Ba	Biotransfer factor for dairy cattle	day/kg FW tissue	constituent specific	
Pork Parameters				
Qp_{forage}	Quantity of forage eaten by swine per day	kg DW plant/day	0	[1]
Qp_{silage}	Quantity of silage eaten by swine per day	kg DW plant/day	1.4	[1]
Qp_{grain}	Quantity of grain eaten by swine per day	kg DW plant/day	3.3	[1]
Qs	Quantity of soil eaten by swine per day	kg/day	0.37	[1]
Ba	Biotransfer factor for swine	day/kg FW tissue	constituent specific	
Chicken (domestic and wild) Parameters				
Qp_{forage}	Quantity of forage eaten by chicken per day	kg DW plant/day	0	[1]
Qp_{silage}	Quantity of silage eaten by chicken per day	kg DW plant/day	0	[1]
Qp_{grain}	Quantity of grain eaten by chicken per day	kg DW plant/day	0.2	[1]
Qs	Quantity of soil eaten by chicken per day	kg/day	0.022	[1]
Ba	Biotransfer factor for chicken	day/kg FW tissue	constituent specific	
Game Parameters				
Qp_{forage}	Quantity of forage eaten by game per day	kg DW plant/day	1.463	[2]
Qp_{silage}	Quantity of silage eaten by game per day	kg DW plant/day	0	[3]

Table 7-9 Modeling Parameters for Estimating Exposure Point Concentrations in Biota for Human Consumption

Parameter	Description	Units	Value	Reference
Qp_{grain}	Quantity of grain eaten by game per day	kg DW plant/day	0	[3]
Qs	Quantity of soil eaten by game per day	kg/day	0	[3]
Ba	Biotransfer factor for game	day/kg FW tissue	constituent specific	
Fish Parameters				
f_{lipid}	Fish lipid content	unitless	0.07	[1]
OC_{sed}	Fraction of organic carbon in bottom sediment	unitless	0.04	[1]

[1] EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, Final, EPA/530/R-05/006. September 2005. US Environmental Protection Agency, Washington DC.

[2] Higley, K. A., and R. Kuperman, 1996. "Ecotoxicological benchmarks for radionuclide contaminants at RFETS, Appendix C," EAD Argonne National Laboratory Report RF/ER-96-0039. Assumes average for mule deer.

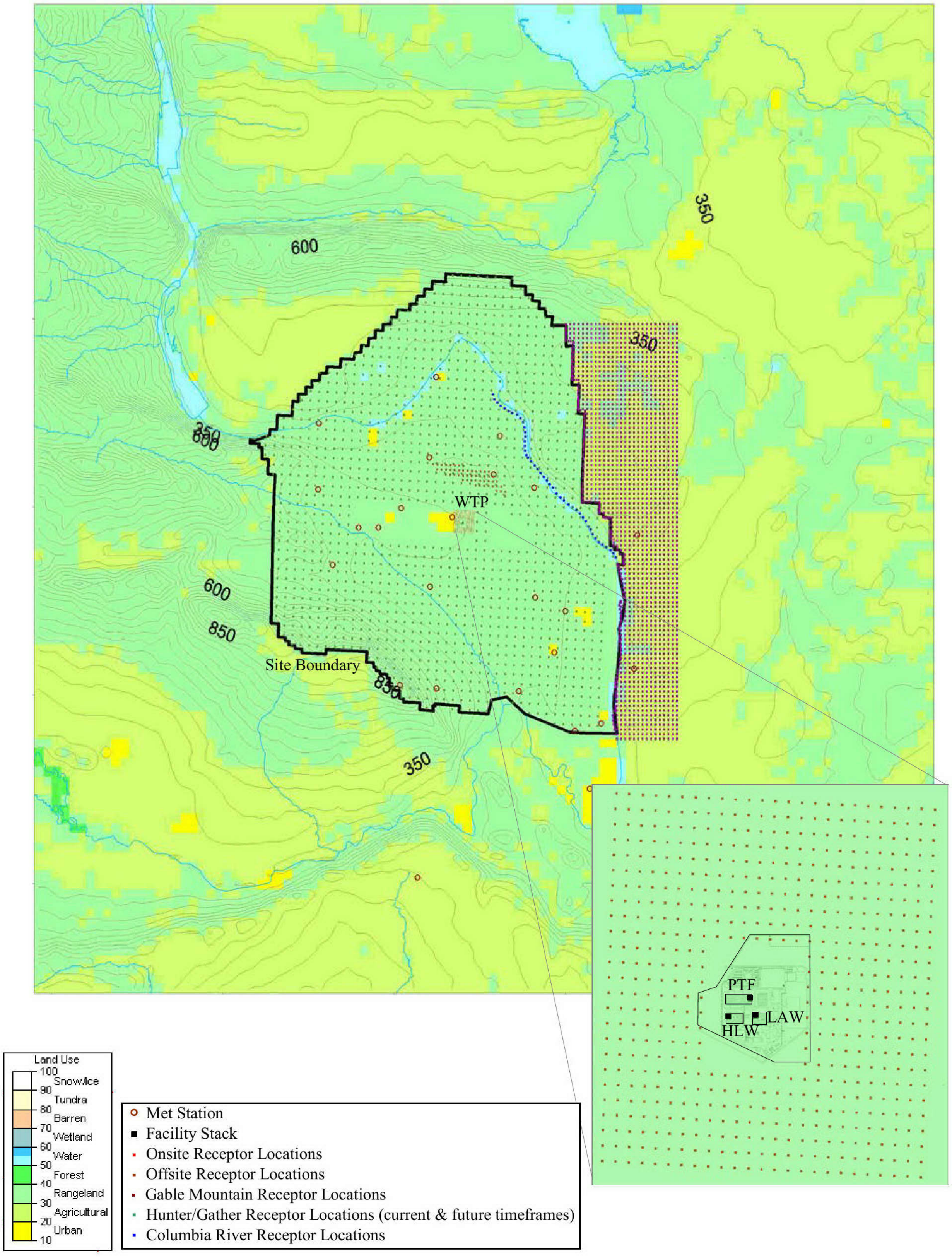
[3] No data available - assumed value

Table 7-10 Toxicity Surrogates

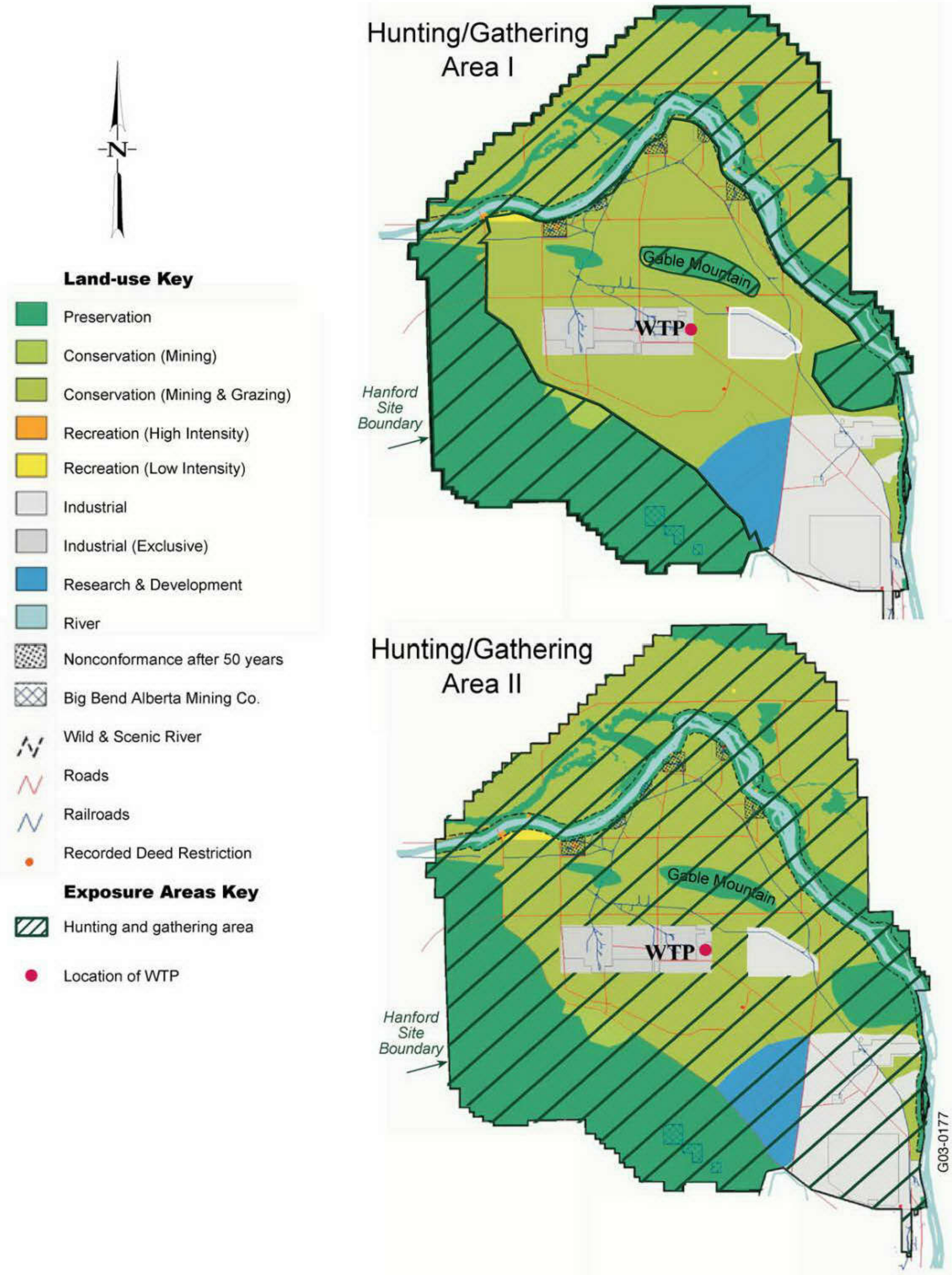
Constituent	Surrogate
Petroleum hydrocarbons	The Washington State *Model Toxics Control Act* (Ecology 2001) method will be used to calculate surrogate toxicity values for the inhalation pathway for hydrocarbons lacking chemical-specific values.
methyl isocyanate (CAS #624-83-9)	acrylonitrile (CAS #107-13-1)
and cis-1,3-dichloropropene (CAS #10061-01-5)	cis-1,2-dichloroethene (CAS #156-59-2)
trichlorofluoroethane (CAS #27154-33-2)	trichlorofluoromethane (CAS #75-69-4)
5-nitroacenaphthene (CAS #602-87-9)	Acenaphthene (CAS #83-32-9)
sec-butyl benzene (CAS #135-98-8)	tert-butyl benzene (CAS #98-06-6)
dichloropentadiene (CAS #61626-71-9)	chlorocyclopentadiene (CAS #41851-50-7)

1 **Figure 7-1 Exposure Assessment Grids**

2

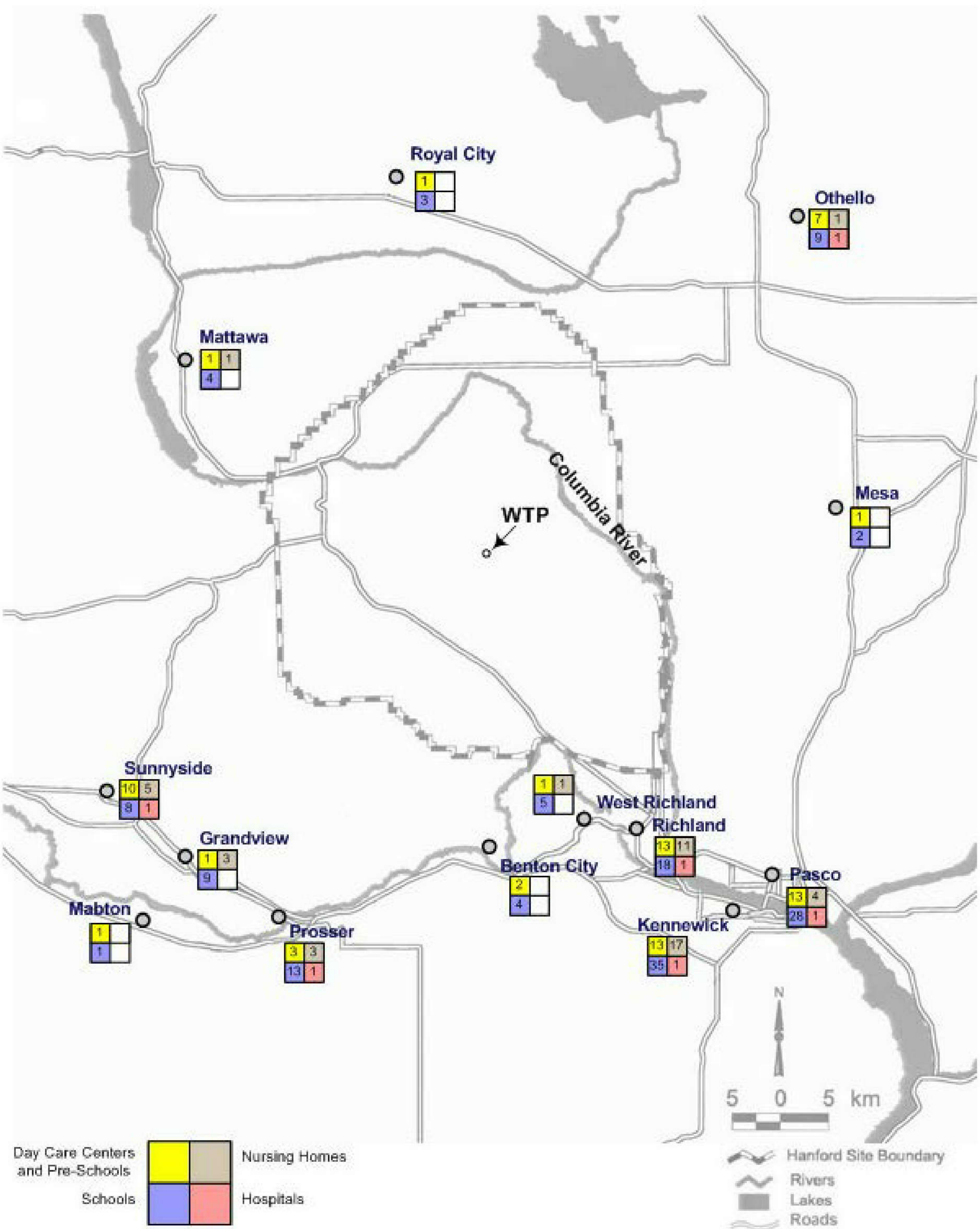


1 **Figure 7-2 Resident Subsistence American Indian Hunting and Gathering Areas**



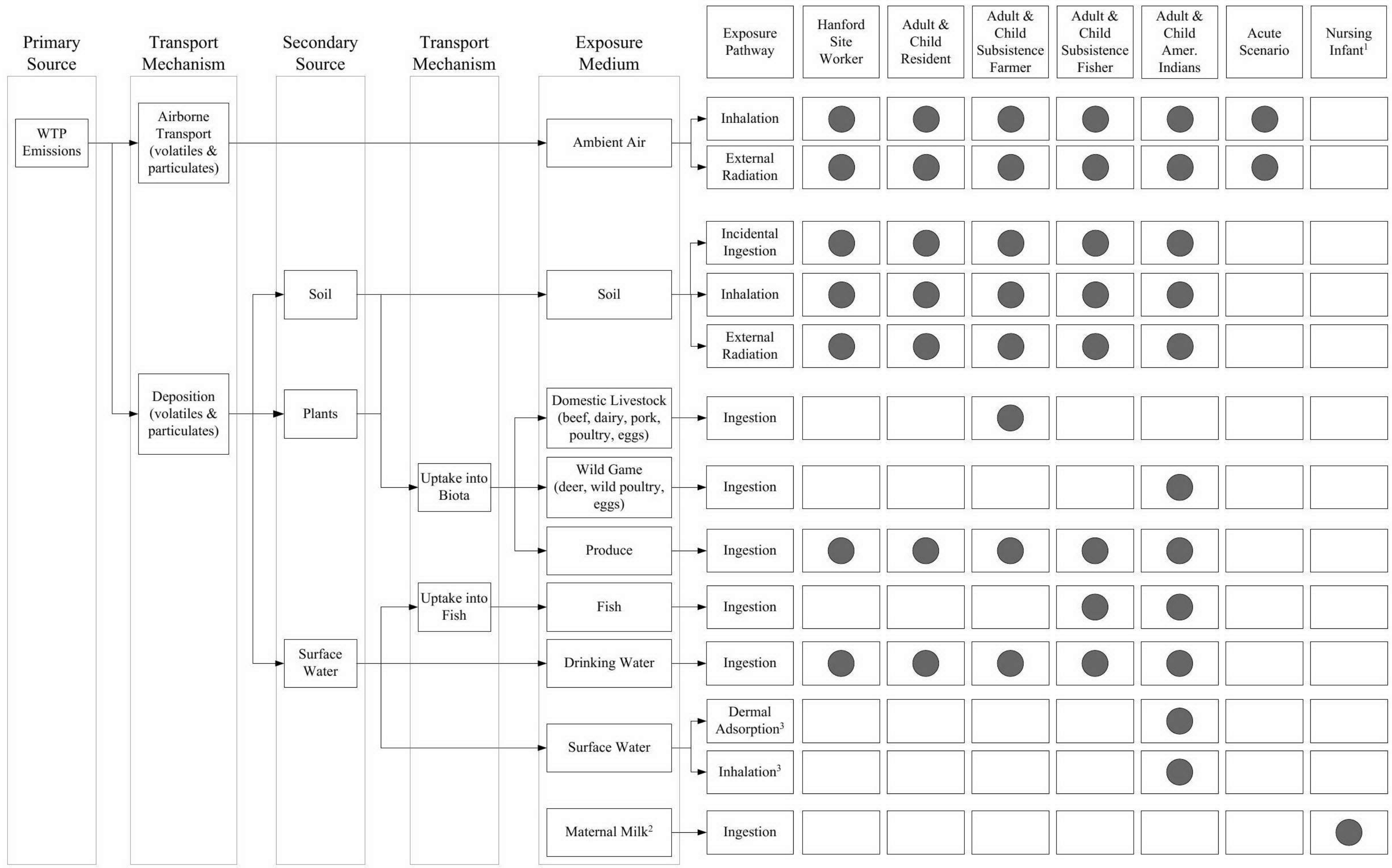
2

1 **Figure 7-3 Locations of Potential Human Receptors including Potentially Sensitive Receptors**



2

Figure 7-4 Human Health Conceptual Exposure Model

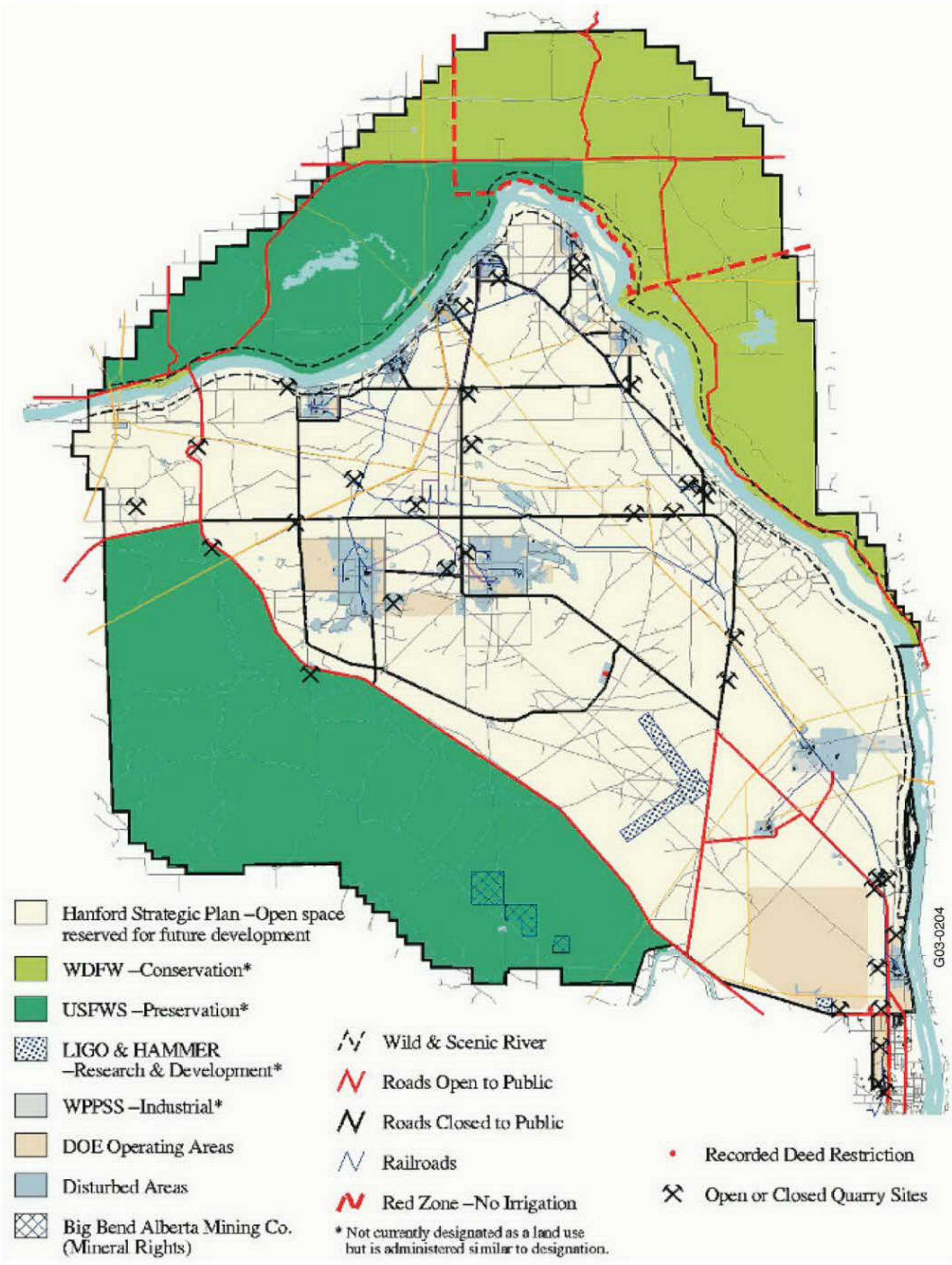


Notes:
[1] Nursing infant is evaluated for the worker, resident, farmer, fisher, and tribal exposure scenarios
[2] Maternal milk pathway assumes maternal exposure to all media for the applicable adult receptor exposure scenario
[3] Sweat lodge exposure is a pathway unique to tribal exposures and includes adsorption and inhalation of water vapor/aerosols

Pathway not complete

Pathway complete and evaluated in screening human health risk assessment

1 **Figure 7-5 Hanford Site Existing Land Use Map - 1996**

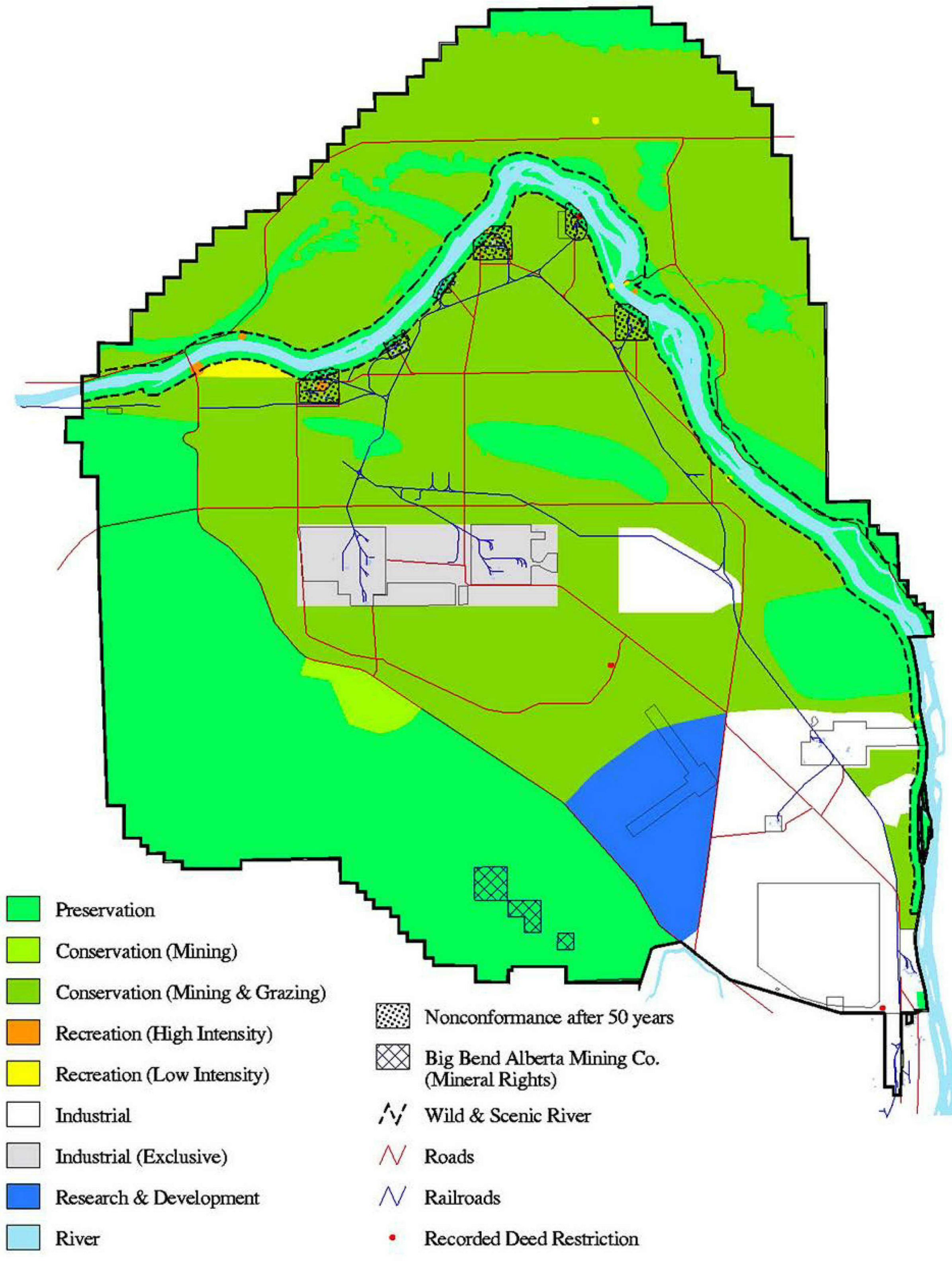


BHI:rpp 04/23/98 clup/noactionalt.aml Database: 07-DEC-1998

WDFW	Washington Department of Fish and Wildlife
USFWS	U.S. Fish and Wildlife Service
LIGO	Laser Interferometer Gravitational Wave Observatory
HAMMER	Hazardous Materials Management and Emergency Response
WPPSS	Washington Public Power Supply System

2

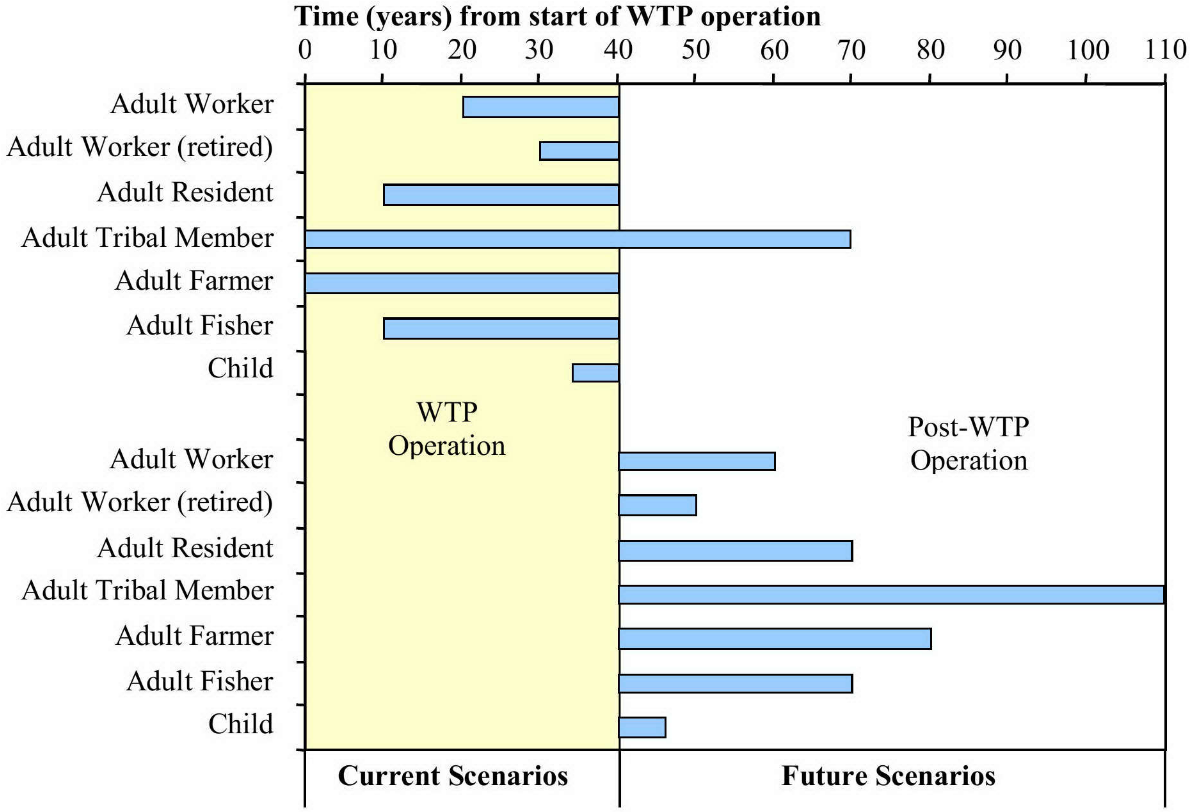
1 **Figure 7-6 Hanford Site Projected Land Use Map - 2046**



2
3

BHI:rpp 04/23/98 clup/prefalt.aml Database: 07-DEC-1998

Figure 7-7 Receptor Exposure Timeline



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8 Screening-Level Ecological Risk Assessment

The screening-level ecological risk assessment (SLERA) incorporates four fundamental components of the ERA process: (1) problem formulation, (2) exposure assessment, (3) effects assessment, and (4) risk characterization. Selection of COPCs and ROPCs (discussed in Section 4 of this work plan), quantification of emissions (discussed in Section 5), and dispersion modeling (discussed in Section 6) feed critical information to this process. The SLERA is intended to meet three goals identified in EPA draft guidance (SLERAP, EPA 1999): the SLERA (1) provides the maximum, most conservative exposure estimate, (2) "identifies which pathways are driving risk specific to a COPC and receptor," and (3) "allows risk management efforts to be prioritized." These methods will be used for both the PRA and the FRA, which will differ in that the PRA will use soil and surface water concentrations modeled from estimated stack emissions, whereas the FRA will use soil and surface water concentrations that are based on the results of a performance demonstration test using surrogate waste as well as estimated stack emissions. The WTP recognizes that there are significant limitations to using a limited performance demonstration test to predict the ability of the melter offgas systems to control emissions. However, proven thermal treatment approaches will be used to select test constituents that are representative of the worst-case constituents and operating conditions so that a conservative estimate of performance is obtained.

8.1 Problem Formulation

This section of the RAWP focuses on the conceptual exposure model (Section 8.1.1), ecological setting (Section 8.1.2), ecological receptor identification (Section 8.1.3), and assessment/measurement endpoints (Section 8.1.4). Each is defined below.

8.1.1 Ecological Conceptual Exposure Model

A conceptual exposure model has been developed that identifies ecological receptors and complete exposure pathways (i.e., exposure scenarios). The conceptual exposure model is shown as Figure 8-1. The end product of the conceptual exposure model is the identification of exposure scenarios that are defined by exposure pathways and potentially exposed populations. The conceptual model was developed from information obtained from EPA (1999) and *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE-RL 1998).

The conceptual model focuses on identifying complete exposure pathways for potentially exposed receptor populations. An exposure pathway is the means through which an organism comes in contact with a chemical or radionuclide in the environment. Exposure pathways are determined by environmental conditions (such as location of habitat and home ranges as well as wind speed/direction), the potential for chemical migration among media (such as air, soil, or surface water), and the behavior and diet of potentially-exposed plant and animal populations. Although several potential pathways may exist, not all pathways may be complete. For a pathway to be complete, all of the following four factors must exist:

1. a source of COPC or ROPC release into the Hanford Site environment
2. a release and transport mechanism (such as deposition to soil) that moves the COPC or ROPC from the source, such as a stack, to other locations in the environment

3. a point of contact with a contaminated medium
4. an exposure route to the receptor, such as ingesting or inhaling affected media

These four factors were considered in the conceptual model. The sources of COPC and ROPC release are the stack and process cell emissions from the WTP (Section 3). Air dispersion (Section 6.1), soil and surface water accumulation (Sections 6.2 and 6.3, respectively), potential points of contact, and complete exposure pathways are identified to formulate exposure scenarios that will be the focus of the quantitative risk assessment.

8.1.2 Ecological Characterization

The ecological setting and habitats at Hanford and offsite locations determine what receptors will be potentially exposed and the important complete pathways. For example, deserts and water bodies have different receptors and exposure pathways. The habitats, food webs, and receptors are the same for both the Hanford Site and offsite locations. The Hanford Site and offsite locations for approximately 100 km in any direction are located in the shrub-steppe region of the Columbia Basin (Daubenmire 1970). The shrub-steppe vegetation zone historically included a shrub overstory and an understory of grasses. The typical plant and animal communities at the Hanford Site and adjacent offsite areas are qualitatively similar. Populations of disturbance-intolerant native species are likely smaller and populations of invasive and native species more tolerant of disturbance are likely larger in offsite areas disturbed by agriculture, grazing, and urbanization. Ecological resources at the Hanford Site are extensive, diverse, and important, as explained by Neitzel et al. (2005). The Hanford Site, unlike adjacent areas, has not been farmed or grazed for over 50 years. It has become a refuge for a variety of plant and animal species (Gray and Rickard 1989), containing one of the largest remaining undisturbed shrub-steppe ecosystems in Washington State (see Appendix C for a listing of plants and animals observed on the site). About 665 km^2 (257 mi^2) of undeveloped lands located on site (almost half of the total area of the Hanford Site) have been designated as ecological study areas or refuges (Figure 8-2).

8.1.2.1 Physiographic Setting

The Hanford Site and adjacent region lie within the Intermountain Semidesert Province (USFS 1994). This province includes the plains and plateaus of the Columbia-Snake River Plateau and the Wyoming Basin. The climate is cool, the average temperature being about 50 °F, and semi-arid, with the average annual precipitation ranging from approximately 6 inches to 20 inches across the province from west to east. At the Hanford Site, the average annual precipitation totals about 6 inches. This precipitation is evenly distributed throughout the fall, winter, and spring months, with little precipitation during the summer months.

The Hanford Site and adjacent region lie within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State. The Hanford Site occupies an area of approximately 1450 km^2 (560 mi^2) north of the confluence of the Yakima River with the Columbia River. The Pasco Basin lies within the southwest corner of the larger Columbia Basin. The Hanford Site occupies approximately one-third of the land area within the Pasco Basin. The Columbia River flows through the northern part of the Hanford Site and forms part of the Hanford Site's eastern boundary after turning south. The Yakima River runs near the southern boundary. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries of the Hanford Site. The Saddle Mountains form the northern boundary. Adjoining lands to the west, north, and east are principally range and agricultural land. The

Hanford Site exhibits low relief, ranging from 120 m above mean sea level (MSL) at the Columbia River to 230 m MSL in the vicinity of the WTP sites.

The 200 Area and WTP site are located on the Central Plateau. The Central Plateau is characterized by generally low-relief hills with deeply incised river drainages. Gable Butte and Gable Mountain (small east to west ridges), located north of the Central Plateau, are characterized by folded layers of rock that are the high points along the Umtanum anticlinal ridge (Neitzel et al. 2005).

8.1.2.2 Regional Ecology

The region comprising the Hanford Site and offsite locations has been characterized as shrub-steppe. The National Biological Service has identified native shrub and grassland steppes in Washington and Oregon as endangered ecosystems (DOE 1999).

Biodiversity in the region is enhanced by the large, relatively undisturbed tract of native shrub-steppe habitat on the Hanford Site and by the Hanford Reach, a stretch of the Columbia River below the Priest Rapids Dam (DOE 1999). Additional factors influencing biodiversity include topographic features such as Rattlesnake Mountain, Gable Butte, Gable Mountain, and the presence of a variety of soils ranging from sand to silty and sandy loam. Unique terrestrial habitats include basalt outcrops, scarps (cliffs), scree slopes, and sand dunes. Offsite areas likely have similar unique habitats. Aquatic habitats are mostly associated with the Columbia River and include open water habitat, wetlands, and riparian areas (Figure 8-4).

Cold Creek and a tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system that roughly parallel State Route 240 through the Hanford Site. Both streams drain areas to the west of Hanford Site. Surface flow, when it occurs, infiltrates and disappears into the surface sediments in the western portion of the Hanford Site. Rattlesnake Springs, located on the western portion of the Hanford Site, forms a small surface stream that flows for about 3 km (1.8 mi) before disappearing into the ground (Figure 8-3).

West Lake is a small saline pond located north of the 200 East Area (Figure 8-2) and is recharged from groundwater (Neitzel et al. 2005). West Lake has not received direct effluent discharges from any Hanford Site facilities. This water body is created by an elevated water table within a low surface area south of Gable Mountain. This artificially elevated water table occurs under much of the Hanford Site, reflecting the augmented recharge from Hanford Site operations. The water level and size of the lake has been decreasing over the past several years because of reduced wastewater discharge (Neitzel et al. 2005).

Gable Mountain Pond (also to the north of the 200 East Area but south of West Lake) and the B Pond System (immediately east of the 200 East Area) received cooling water discharges from several facilities at the Hanford Site (Rogers and Rickard 1977). These artificial water bodies, formed by the wastewater discharges from the operation of the separation facilities, were decommissioned and covered with soil.

The 200 Area Treated Effluent Disposal Facility (TEDF) disposal ponds (east of the 200 East Area) consists of two disposal ponds that receive industrial wastewater permitted in accordance with Ecology's State Waste Discharge Permit Program (WAC 173-216). The wastewater evaporates into the air or percolates into the ground from the disposal ponds (Neitzel et al. 2005).

There are several naturally occurring vernal ponds near Gable Mountain and Gable Butte. These ponds appear to occur where a depression is present in a relatively shallow buried basalt surface. Water collects within the depression over the winter, resulting in a shallow pond that dries during the summer months (Neitzel et al. 2005).

Vegetation

The Columbia Basin (Daubenmire 1970) is a shrub-steppe ecosystem characterized by bunchgrasses and sagebrushes (Figure 8-4). This ecosystem is also referred to as high desert, northern desert shrub, or desert scrub (Franklin and Dyrness 1973). Prior to settlement by western Europeans, the dominant plant in the area was big sagebrush (*Artemisia tridentata*) with an understory of perennial bunchgrasses, especially Sandberg's bluegrass (*Poa sandbergii*) and bluebunch wheatgrass (*Agropyron spicatum*). Following settlement in the early 1800s, grazing and agriculture disrupted the native vegetation and opened the way for invasive species such as Russian thistle (*Salsola kali*) and cheatgrass (*Bromus tectorum*). Cheatgrass is now dominant in fields that were cultivated prior to the establishment of the Hanford Site. Cheatgrass also is well established on rangelands at elevations less than 244 m (800 ft) (DOE 1999). Establishment of the Hanford Site as a nuclear complex in 1943 resulted in the creation of a secured area of mostly undeveloped land with scattered, small industrial facilities. Consequently, the Hanford Site is one of a small number of remaining shrub-steppe tracts in Washington State that is relatively undisturbed. Wildfire is a common occurrence and can significantly alter the shrub component of the vegetation. The most recent extensive fire on the Hanford Site was in 2000 and burned over 660 km^2 (250 mi^2).

Trees were planted and irrigated on most of the pre-1943 farms to provide windbreaks and shade. Some of these trees have persisted and serve as nesting platforms for several species of birds (hawks, owls, ravens, magpies, and great blue herons) and as night roosts for wintering bald eagles (DOE 1999) (Figure 8-5).

A total of 727 species representing 90 families of vascular plants are recorded for the Hanford Site (Neitzel et al. 2005). The dominant plants are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass, with cheatgrass providing half of the total plant cover on much of the Hanford Site. Cheatgrass and Russian thistle are annuals introduced to the United States from Eurasia in the late 1800s that invade disturbed areas. Big sagebrush and bitterbrush (*Purshia* spp.) are widely spaced and usually provide less than 20 % canopy cover. Bitterbrush provides important browse for the resident mule deer herd. The dominant understory plants are grasses, especially cheatgrass, Sandberg's bluegrass, Indian ricegrass (*Oryzopsis hymenoides*), June grass (*Koeleria macrantha*), and needle-and-thread grass (*Stibacomata*).

Central Plateau. The Central Plateau and surrounding areas in the Columbia Basin have been identified as predominantly shrub-steppe (Duranceau 1995). This designation includes communities dominated by big sagebrush and bitterbrush (*Purshia tridentata*) with an understory of cheatgrass or Sandberg's bluegrass. Past wildfires in the Central Plateau have opened up some areas, creating a mosaic of shrub- and grass-dominated areas. More than 100 species of plants have been identified on the Central Plateau (Cushing 1992). Big sagebrush, bitterbrush, cheatgrass, and Sandberg's bluegrass are common species within the 200 Area (Neitzel et al. 2005). Cheatgrass provides approximately 50 % of the total plant cover. Cheatgrass also is common where native plant communities have been disturbed by wildfire or past construction activities. Three vegetation subtypes occurring in the vicinity of the 200 West Area of the Central Plateau are sagebrush and Sandberg's bluegrass, sagebrush and needle-and-thread grass, and spiny hopsage and Sandberg's bluegrass.

The WTP site in and immediately surrounding the 200 East Area is approximately 40 % big sagebrush and rabbitbrush (Figure 8-6). Another 20 % is dominated by Russian thistle, with the remainder being disturbed vegetation or bare gravel (PNL 1994). Other vegetation in the 200 Area includes introduced perennial grasses planted to revegetate and stabilize disturbed areas, such as waste burial grounds. Introduced perennial grasses (e.g., Siberian wheatgrass [*Agropyron sibericum*]) have been used extensively in the Central Plateau to revegetate and stabilize waste burial grounds against wind and water erosion (DOE 1999). Siberian wheatgrass has proven to be drought tolerant and better adapted to sandy soils than other cultivars used in Central Plateau revegetation efforts (Stegen 1993; WHC 1993).

Columbia River. The two major vegetation types occurring along the Hanford Reach of the Columbia River are riparian and upland (NPS 1994). Riparian habitats are found along the shoreline, slack water and slough areas, and on islands in the river. Riparian vegetation at these locations includes both woody and herbaceous species maintained by the high water table immediately adjacent to the river. Common plant species occurring in the riparian zone include water smartweed, sedges, reed canary grass, bulbous bluegrass, common witchgrass, large barnyard, willow, mulberry, and Siberian elm (Neitzel et al. 2005). Sensitive habitats within the riparian zone include islands and cobbled shorelines occurring as a narrow band along the Hanford Reach. Plant species occurring in these areas include perennial, summer-blooming forbs adapted to seasonal changes in water levels (NPS 1994). Upland habitats along the Hanford Reach are composed of shrub-steppe vegetation similar to that found on the Central Plateau (DOE 1999). Sand dunes are often colonized by needle-and-thread grass on the north-facing slopes and a mixture of shrubs and forbs at the crest (Sackschewsky et al. 1992).

In summary, special topographic features on the Hanford Site include Gable Butte and Gable Mountain north of the Central Plateau and an extensive series of active sand dunes in the southeast portion of the area. The dominant plant communities are cheatgrass, sagebrush-bitterbrush and Sandberg's bluegrass, sagebrush and cheatgrass, Sandberg's bluegrass, and riparian plant communities (Sackschewsky et al. 1992). Depending on the location, many of the terrestrial plants occurring in this area are the same as those found in the adjacent Columbia River and Columbia Basin. Big sagebrush, bitterbrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass are common species in the area just north of the 300 Area in the southeast corner of the Hanford Site (Neitzel et al. 2005). Common plants growing in riparian areas along the Columbia River include reed canarygrass, common witchgrass, large barnyard grass, summer-blooming forbs, sandbar willow, poplar, white mulberry, and Russian olive (NPS 1994). Vegetation occurring on scree slopes, outcrops, and scarps such as those on Gable Butte and Gable Mountain is limited to scattered individuals and groups of plants. Plant species include squaw currant, bluebunch wheatgrass, rock buckwheat, and thyme buckwheat. Rigid sagebrush (*Artemesia rigida*) occurs at the Hanford Site only on Gable Mountain and Umtanum Ridge (Downs et al. 1993).

Wildlife

Approximately 300 species of terrestrial vertebrates have been observed at the Hanford Site. This number includes 46 species of mammals, 246 species of birds, 6 species of amphibians, and 7 species of reptiles (Neitzel et al. 2005).

Mammals. Large herbivorous mammalian species that are found on the Hanford Site and offsite area include mule deer and Rocky Mountain elk. Mule deer (*Odocoileus hemionus*) are most often found near the Columbia River and use Columbia River islands for fawning and nursery areas. Rocky Mountain elk (*Cervus elaphus*) began to appear on the Hanford Site during the early 1970s and are generally restricted to the FEALE Reserve. Elk frequently move off the reserve to private lands to the north and west, particularly during late spring, summer, and early fall (Neitzel et al. 2005).

Black-tailed jackrabbits (*Lepus californicus*) are common on the Hanford Site and offsite area and are most often found in mature stands of sagebrush. Cottontail rabbits (*Sylvilagus* spp.) also are common but are more closely associated with developed areas. Townsend's ground squirrels (*Spermophilus* *townsendii mollis*) occur in colonies of various sizes scattered across the Hanford Site and offsite areas. The most abundant mammal inhabiting the site is the Great Basin pocket mouse (*Perognathus parvus*). This mouse occurs all across the Columbia Basin and on the slopes of the surrounding ridges. Other small mammals include the western harvest mouse (*Reithrodontomys megalotis*), grasshopper mouse (*Onychomys leucogaster*), deer mouse (*Peromyscus maniculatus*), house mouse (*Mus musculus*), mountain vole (*Microtus montanus*), sagebrush vole (*Lagurus curtatus*), brushy-tailed woodrat (*Neotoma cinerea*), northern pocket gopher (*Thomomys talpoides*), vagrant shrew (*Sorex vagrans*), and Merriam's shrew (*Sorex merriami*) (DOE 1999). In addition to mule deer, mammals occurring primarily in riparian areas include rodents (muskrat [*Ondatra zibethica*]); furbearers (mink [*Mustela vison*], River otter [*Lutra canadensis*], weasel [*Mustela spp.*]); porcupine (*Erithizon dorsatum*); raccoon (*Procyon lotor*); and skunk (*Mephitis mephitis*) (Neitzel et al. 2005).

Common mammalian predators are the coyote (*Canis latrans*), bobcat (*Lynx rufus*), and badger (*Taxidea taxus*). These carnivores feed primarily on the several species of small mammals, including the Great Basin pocket mouse, western harvest mouse, grasshopper mouse, deer mouse, house mouse, Townsend's ground squirrel, mountain vole, sagebrush vole, black-tailed jackrabbit, brushy-tailed woodrat, and northern pocket gopher. Coyotes have been a major predator of Canada goose (*Branta canadensis leucopareia*) nests on Columbia River islands, especially upstream from the abandoned Hanford townsite (DOE 1999). There was a reported sighting of a cougar (*Felis concolor*) on ALE Reserve by experienced biologists during the elk relocation effort in March 2000 (Neitzel et al. 2005).

Up to 14 species of bats are known to be or have the potential to be present on or in the vicinity of the Hanford Site. They include the pallid bat (*Antrozous pallidus*), hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagan*), little brown bat (*Myotis lucifugus*), California brown bat (*Myotis californicus*), Yuma brown bat (*Myotis yamanensis*), and Pacific western big-eared bat (*Plecotus townsendii*) (Fitzner and Gray 1991). The pallid bat, which roosts in abandoned buildings, is considered to be the most abundant. All of these bat species feed on flying insects.

Birds. Nearly 250 species of birds occur on or near the Hanford Site as year-round residents, seasonal residents, migrants, and accidentals. There are 144 bird species considered common to the Hanford Site (Neitzel et al. 2005).

Eleven raptors have been documented as nesting on the Hanford Site. These include the northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), American kestrel (*Falco sparverius*), barn owl (*Tyto alba*), great horned owl (*Bubo virginianus*), long-eared owl (*Asio otus*), short-eared owl (*Asio flammeus*), and burrowing owl (*Athene cunicularia*) (Fitzner and Gray 1991, Rickard et al. 1988). Raptors use a variety of habitats for nesting and foraging on the Hanford Site. Nesting habitats include outcrops, cliffs, trees, marshes, fields, and utility towers. Depending on raptor species, prey may include small mammals, birds, reptiles (i.e., snakes), and insects.

Great blue herons (*Ardea herodias*) and black-crowned night herons (*Nycticorax nycticorax*) are associated with trees in riparian habitat along the Columbia River and use groves or individual trees for perching and nesting. On occasion, great blue herons have constructed nests in the large metal powerline towers that are present on the shores of the Columbia River (Neitzel et al., 2005).

Several songbird species occur in the shrub-steppe vegetation throughout the region. These include the western meadowlark (*Sturnella neglecta*), grasshopper sparrow (*Ammodramus savannarum*), horned lark (*Eremophila alpestris*), and sage thrasher (*Oreoscoptes montanus*) (Downs et al. 1993). The western meadowlark and horned lark are the most abundant breeding bird species within the shrub-steppe habitat (Rickard and Poole 1989). These two species nest on the ground in the open, while other species (such as sage sparrow, sage thrasher, and loggerhead shrike) require sagebrush or bitterbrush as nesting structures. Long-billed curlews (*Numenius americanus*) and vesper sparrows (*Pooecetes gramineus*) have also been noted as commonly occurring species in shrub-steppe habitat. Songbird species that occur in riparian habitats include the red-winged blackbird (*Agelaius phoeniceus*), American robin (*Turdus migratorius*), black-billed magpie (*Pica pica*), song sparrow (*Melospiza melodia*), and dark-eyed junco (*Junco hyemalis*). Species known or expected to nest in riparian habitat are Brewer's blackbird (*Euphagus cyanocephalus*), mourning dove (*Zenaida macroura*), black-billed magpie (*Pica pica*), northern oriole (*Icterus galbula*), lazuli bunting (*Passerina amoena)*, eastern kingbird (*Tyrannus tyrannus*), western kingbird (*Tyrannus verticalis*), and western wood peewee (*Contopus sordidulus*) (Neitzel et al. 2005).

The Hanford Reach serves as a resting area for neotropical migrant birds, migratory waterfowl, and shorebirds. The area between the old Hanford townsite and Vernita Bridge is closed to recreational hunting, and large numbers of migratory waterfowl find refuge in this portion of the river. Other species observed during this period include American white pelicans (*Pelecanus erythrorhynchos*), egrets (*Casmerodius albus*), doublecrested cormorants (*Phalacrocorax auritus*), coots (*Fulica americana*), and common loons (*Gavia immer*). Shoreline riparian communities are seasonally important for a variety of species. Willows trap food for waterfowl (e.g., Canada geese [*Branta canadensis*]) and birds that use shoreline habitat (e.g., Forster's tern [*Sterna forsteri*]) as well as providing nesting habitat for passerines (e.g., mourning doves [*Zenaida macroura*]) (Neitzel et al. 2005).

Common upland game bird species include the chukar partridge (*Alectoris chukar*), grey partridge (*Perdix perdix*), California quail (*Callipepla californicus*), and Chinese ring-necked pheasant (*Phasianus colchicus*). Greater sage grouse (*Centrocercus urophasianus*) and scaled quail (*Callipepla squamata*) are less common and are rarely seen. Greater sage grouse were observed on ALE Reserve during 1999 and 2000; however, a fire in 2000 destroyed potential greater sage grouse habitat, and it is unlikely that greater sage grouse will return in numbers until the vegetation has recovered to a point where it can support them (Neitzel et al. 2005). None of the upland birds are native to the area except the sage grouse.

Reptiles and Amphibians. Seven species of reptiles and six species of amphibians are found at the Hanford Site. The side-blotched lizard (*Uta stansburiana*) is the most abundant reptile (Neitzel et al. 2005). The short-horned lizard (*Phrynosoma douglassii*) and northern sagebrush lizard (*Sceloporous graciosus*) are also common in mature sagebrush habitats with sandy soil. Commonly encountered snakes include the gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and western rattlesnake (*Crotalus viridis*). Less common is the striped whipsnake (*Masticophis taeniatus)*. Amphibians on the Hanford Site are associated with riparian habitats located along the Columbia River or other permanent water bodies (Fitzner and Gray 1991). Species include the Great Basin spadefoot toad (*Spea intermontana*), western toad (*Bufo boreas*), Woodhouses toad (*Bufo woodhouseii*), the Pacific tree frog (*Hyla regilla*), tiger salamander (*Ambystoma tigrinum*), and bullfrog (*Rana catesbeiana*) (Neitzel et al. 2005). These reptiles and amphibians also occur at offsite locations.

Terrestrial Invertebrates. Most of the terrestrial invertebrate species on the Hanford Site and offsite locations are insects and spiders. Butterflies, grasshoppers, and darkling beetles represent some of the more conspicuous insect groups. The populations of all three of these species of insects are subject to seasonal changes and weather variations (Rogers and Rickard 1977). Many of the insect species are important in the food web of birds and mammals found on the Hanford Site. Species like the darkling beetle play an important role in the decomposition process by feeding on decaying plant material, animal feces, fungi, and live plant tissue (Weiss and Mitchell 1992). Spiders are also abundant, especially in the riparian and shrub-steppe habitat (DOE 2001).

The Nature Conservancy has identified nearly 1680 species of insects on the Hanford Site (Evans et al. 2003). A collection of 12,000 specimens in 2003 resulted in the identification of 376 taxa and an estimated 150-200 new findings in the state of Washington, 46 from Hanford studies conducted over the last decade. Numerous species not previously collected at Hanford, especially in the orders Trichoptera (caddisflies) and Lepidoptera (moths), have been added to the invertebrate fauna of the Hanford Site. The actual number of insect species occurring on the Hanford Site may reach as high as 15,500 (Neitzel et al. 2005).

Distribution of Wildlife. Because the habitats of the Central Plateau are considerably different from those near the Columbia River, terrestrial animals are described separately for those locations in the following paragraphs.

Central Plateau: A characterization study of small mammals performed south of the 200 East Area resulted in the trapping of the following five species: the Great Basin pocket mouse, deer mouse, northern grasshopper mouse, sagebrush vole, and western harvest mouse (Rogers and Rickard 1977). The Great Basin pocket mouse represented more than 90 % of the individuals caught. Medium- and large-size mammals that may occur in the Central Plateau include rabbits, coyotes, badgers, and mule deer (Rogers and Rickard 1977). Some of these organisms are receptors in the SLERA. Other mammals potentially using areas associated with ponds and ditches in the 200 Area include muskrats, porcupines, and raccoons (DOE 1999). Many common bird species, such as the western meadowlark and sage sparrow, are likely to occur on the Central Plateau where suitable habitats exist. Thirty-seven species of terrestrial birds were recorded during surveys conducted in the 200 Area in 1986 (Schuler et al. 1993).

Unique habitats can be found on Gable Butte and Gable Mountain situated north of the Central Plateau. These unique habitats include basalt outcrops, scarps, and scree slopes. Birds likely to occur in these habitats are the prairie falcon, rock wren, poorwill, and chukar; small mammals include the yellow-bellied marmot and wood rat; reptiles include rattlesnakes, gopher snakes, and horned lizards (Downs et al. 1993).

Columbia River: Terrestrial wildlife species use both shoreline riparian and shrub-steppe habitats occurring along the Columbia River and on the islands. Wildlife reported to use the Hanford Reach includes 184 species of birds, 36 species of mammals, 9 species of reptiles, and 4 species of amphibians (NPS 1994). The Canada goose uses islands along the Hanford Reach extensively for nesting. Monitoring of nesting geese that use the Hanford Site has been ongoing since 1950. These studies indicate that Canada geese nest more frequently on islands in the downstream reach because of heavy predation by coyotes further upstream (Neitzel et al. 2005). Mule deer use the islands and other riparian areas for fawning habitat. Wildlife occurring in shoreline habitat includes 46 species that use willow communities and 49 species that use grass areas (NPS 1994).

The Hanford Reach begins at the foot of Priest Rapids Dam in the northwest portion of the area within a 50-km radius of the WTP stacks. It extends through the Hanford Reservation to the reservoir of McNary Dam, just north of the city of Richland. The Hanford Reach includes a variety of habitat types, including those also found outside the Hanford Reach but within the 50 km radius. Therefore, biota in and outside of the Hanford Reach are expected to be similar. Evaluating risks wherever the concentration in the Columbia River is highest helps ensure that biota in the 50 km radius are protected.

8.1.2.3 Aquatic Ecosystems

Washington State has classified the stretch of the Columbia River that includes the Hanford Reach as Class A, Excellent (Neitzel et al. 2005). Class A waters must be suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat. Water from the Columbia River is used for both irrigation and municipal water supplies. Federal and state drinking water quality standards apply to the Columbia (Neitzel et al. 2005). Water samples from the Columbia River and three ponds on the Hanford Site are routinely collected and analyzed.

The Columbia River supports an ecosystem of plankton, benthic invertebrates, fish, and other communities. Algae are abundant in the river and provide food for herbivores, such as immature insects, which are then eaten by carnivorous species, such as bass. Aquatic plants in the Hanford Reach include water milfoil, waterweed, pondweed, Columbia yellowcress, watercress, and duckweed. Water milfoil is an aggressive, introduced aquatic plant and is becoming a nuisance in the river. Other aquatic species found in the Hanford Reach include microflora, zooplankton, and benthic invertebrates. Microflora include both sessile types (periphyton) and free-floating types (phytoplankton). Microflora species include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Dominant zooplankton taxa include *Bosmina*, *Diaptomus*, and *Cyclops*. Benthic invertebrate taxa occurring in the Hanford Reach include insect larvae such as caddisflies (*Trichoptera*), midge flies (*Chironomidae*), and black flies (*Simuliidae*); clams (*Corbicula* spp., *Anodontia* spp.), snails (*Physa* spp.), freshwater sponges (*Spongilla* spp.), limpets (*Fisherola* spp.), and crayfish (*Astacus trowbridgii*) are also present (Neitzel et al. 2005).

The Hanford Reach and adjacent reaches of the Columbia River support over 40 species of fish. The anadromous chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*) use the river to migrate to and from upstream spawning areas. Chinook salmon and steelhead trout also spawn in the Hanford Reach in the fall (Figure 8-7). Shad (*Alosa sapidissima*) may also spawn in this stretch of river. Mountain whitefish (*Prosopium williamsoni*), white sturgeon (*Acipenser transmontanus*), smallmouth bass (*Micropterus dolomieui*), crappie (*Pomoxis nigromaculatus*), catfish (*Ictalurus punctatus*), walleye (*Stizostedion vitreum*), and yellow perch (*Perca flavescens*) are important game fish to sport fisherman and American Indians. A healthy rough fish population includes carp (*Cyprinus carpio*), redside shiner (*Richardsonius balteatus*), suckers (*Catostomus macrocheilus*), and northern squawfish (*Ptychocheilus oregonensis*) (Neitzel et al. 2005).

West Lake, near the 200 Area, is created by a rise in the water table under the Central Plateau and is not fed by surface flow. This results in the pond being highly saline, as well as alkaline, and having low species diversity (DOE 1999). West Lake, located southwest of Gable Mountain, fluctuates in size with changes in the water table. The water level and size of the lake have been decreasing over the past several years because of reduced wastewater discharge (Neitzel et al. 2005). Unlike other ponds on the Hanford Site, West Lake does not receive direct effluent discharges from Hanford Site facilities (PNL 1993). Wetland vegetation found at West Lake is limited to scattered patches of emergent macrophytes, such as cattails and bulrushes. No jurisdictional wetland has been identified at West Lake.

Other wetland habitats found on the Hanford Site are associated with man-made ponds and ditches occurring on the Hanford Site, including a small cooling and wastewater pond in the 400 Area and the gravel pit converted to wetland at the 100-B Area. These artificial water bodies, formed by the wastewater discharges from the operation of the separation facilities, no longer receive discharges.

8.1.2.4 Threatened and Endangered Species

Species of concern on the Hanford Site and offsite locations include federally listed threatened and endangered (T&E) species, state-listed T&E species, state-listed candidate species, state-listed plant species of concern, and species of ethnobiological concern to American Indians. There are no federal- or state-listed endangered or threatened mammals, reptiles, amphibians, or invertebrates on the Hanford Site, but there are three species of fish, four species of birds, and thirteen species of plants listed as threatened or endangered by either the state or federal governments (PNNL 2010). Table 8-1 summarizes the endangered, threatened, candidate, and species of concern found at the Hanford Site.

The federal species of concern bald eagle (*Haliaeetus leucocephalus*) is found regularly along the Hanford Reach. The anadromous chinook salmon (*Oncorhynchus tshawytscha*) and the steelhead (*Oncorhynchus mykiss*) species are regulated as evolutionarily significant units (ESUs) by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service, based on historical geographic spawning areas. One ESU of the chinook salmon, the Upper Columbia River spring-run ESU, is listed as endangered (Federal Register 1999 [64 FR 14308]). The Middle Columbia River steelhead ESU is listed as threatened (Federal Register 1999 [64 FR 14517]). The Upper Columbia River ESU is the portion of the Columbia River between the US-Canada border and the Yakima River, and it includes the Hanford Reach. One additional threatened fish species (bull trout) has been recorded on the Hanford Site but is believed to be transient (Neitzel et al. 2005).

Washington State lists the American white pelican (*Pelecanus erythrorhynchos*) and sandhill crane (*Grus canadensis*) as endangered, and the ferruginous hawk (*Buteo regalis*) and greater sage grouse (*Centrocercus urophasianus*) as threatened. The bald eagle (*Haliaeetus leucocephalus*), the peregrine falcon (*Falco peregrinus*), and the common loon (*Gavia immer*) are listed as sensitive. The American white pelican is a year-round resident (DOE 2001), the sandhill crane is a rare fall and spring visitor (DOE 2001), and the ferruginous hawk is a breeding resident. The bald eagle is a regular winter resident along the Columbia River (Neitzel et al. 2005). The peregrine falcon is a casual migrant to the Hanford Site between November and January (DOE 2001). The common loon is present year-round (DOE 2001); the temporal habits of the rarely seen greater sage grouse on the Hanford Site are not known (WHC 1992a).

Thirteen species of plants listed by Washington State as T&E are found on the Hanford Site. Two are listed as endangered: Columbia yellowcress (*Rorippa columbiae*) and Umtanum desert buckwheat (*Erigonium codium*); eleven plant species are listed as threatened: awned halfchaff sedge (*Lipocarpha (= Hemicarpha) aristulata*), chaffweed (*Anagallis (=Centunculus) minimus*), desert dodder (*Cuscuta denticulate*), Geyer's milkvetch (*Astragalus geyeri*), grand redstem (*Ammannia robusta*), Great Basin gilia (*Gilia leptomeria*), loeflingia (*Loeflingia squarrosa var. squarrosa*), lowland toothcup (*Rotala ramosior*), rosy pussypaws (*Calyptridium roseum*), White Bluffs bladderpod (*Lesquerella tuplashensis*), and white eatonella (*Eatonella nivea*). The awned halfchaff sedge, chaffweed, Columbia yellowcress, grand redstem, and lowland toothcup are restricted to wetlands in the riparian zone of the Columbia River. Other plant species, such as Great Basin gilia, loeflingia, and rosy pussypaws, are small annuals that have been found in relatively undisturbed sagebrush areas in the vicinity of Gable Mountain. The Great Basin gilia has been identified within the Hanford Reach National Monument. The remaining three state threatened-plant species (Geyer's milkvetch, white eatonella, and desert dodder) have been found at various sites on the Wahluke slope. Two species of plants are candidates for federal protection: the Umtanum desert buckwheat, which occurs in several small, highly localized populations on Umtanum Ridge, and the White Bluffs bladderpod, which occurs on the White Bluffs (Neitzel et al. 2005).

Wildlife state-listed candidate species observed or considered likely to be found on or near the Central Plateau include the sage sparrow (*Amphispiza belli*) and the loggerhead shrike (*Lanius ludovicianus*). Both of these birds commonly nest in undisturbed shrub-steppe habitat. The sage sparrow is one of the most common nesting birds on the Hanford Site (Downs et al. 1993). Other state-listed candidate bird species that may be found include the burrowing owl (*Athene cunicularia*), golden eagle (*Aquila chrysaetos*), sage thrasher (*Oreoscoptes montanus*), and merlin (*Falco columbarius*) (Neitzel et al. 2005). Another state-listed candidate species of concern inhabiting the Central Plateau and vicinity is the striped whipsnake (*Mastocophis taeniatus*).

Central Plateau. No federally or state-listed T&E plant or animal species occur in the Central Plateau (DOE 1999). Several state-listed plant species are found on the Central Plateau.

Wildlife species of state concern occurring in the 200 Area include the loggerhead shrike and sage sparrow. Both species nest in undisturbed sagebrush habitat in the Central Plateau (PNL 1993). Other listed T&E bird species that may occur in shrub-steppe habitat in the Central Plateau are the burrowing owl and golden eagle. Reptile species of concern using the Central Plateau include the striped whipsnake (*Masticophis taeniatus*) (Rogers and Rickard 1977, Neitzel et al. 2005).

Columbia River. No federally listed T&E plant species occur on the Hanford Reach (DOE 1999). State-listed endangered plant species occurring along the Hanford Reach include the Columbia yellowcress. Preferred habitat for persistent sepal yellowcress is shoreline areas with gently sloping, cobbly substrate (PNL 1993). State-listed plant species of concern have been found along the shoreline and on islands of the Hanford Reach between the Vernita Bridge and the 300 Area, including the southern mudwort, dense sedge, and shining flatsedge (WHC 1992b).

State-listed endangered bird species that occur along the Hanford Reach that are considered relatively common include the American white pelican (*Pelecanus erythrorhynchos*) and sandhill crane. State-listed sensitive species include the common loon (*Gavia immer*), the peregrine falcon, and the bald eagle. The common loon is found within the Hanford Reach. The peregrine falcon is an incidental migrant on the Hanford Site (Neitzel et al. 2005). The bald eagle is a relatively common winter resident along the Hanford Reach that occasionally attempts to nest on the Hanford Site. However, bald eagles have never successfully nested on the Hanford Site (Neitzel et al. 2005).

Of the three federally listed fish species, only the upper Columbia River steelhead trout spawns in the Hanford Reach. Upper Columbia River spring Chinook salmon adults pass through the Hanford Reach while migrating to spawning grounds, and the juveniles use the Hanford Reach as a nursery area while they migrate toward the ocean. The bull trout, which primarily inhabits smaller streams at higher elevations, has been observed in the Hanford Reach on very rare occasions, usually associated with the spring freshets. Bull trout are not considered to be residents of the Hanford Site (Neitzel et al. 2005).

8.1.2.5 Sensitive Environments

Sensitive habitats on the Hanford Site include shrub-steppe, and wetlands and riparian habitats (Table 8-1). Shrub-steppe ecosystems are typified by a shrub overstory and a grass and forb understory. Lichens and mosses, often times referred to as “microbiotic or cryptogamic crust,” provide a soil-stabilizing growth on undisturbed soils in the shrub-steppe ecosystem. The dominant vascular plants in the area are big sagebrush, underlain by perennial bunchgrasses and forbs. Over 700 species representing 90 families of vascular plants are recorded for the Hanford Site (Neitzel et al. 2005). Wetlands include those transitional lands occurring between terrestrial and aquatic ecosystems where the water table is usually close to the surface or where shallow water covers the surface (Cowardin et al. 1979). The primary wetlands found on site occur along the Hanford Reach of the Columbia River and include the riparian habitats located along the river shoreline. Other wetland habitats found on the Hanford Site are associated with man-made ponds and ditches. The variety of habitat on the Hanford Site creates special ecological areas. For example, the Hanford Site includes nesting sites for bird species of concern, salmon and steelhead spawning areas, riparian habitat, and part of the largest remaining tract of shrub-steppe habitat in the Columbia Basin (DOE 1999).

There are also special ecological areas outside the Hanford Site but within the area included in deposition modeling. These include the Columbia National Wildlife Refuge, which extends from approximately 30 km to approximately 50 km north of the WTP, and habitats classified as priority habitats by the state of Washington. Priority habitats near the Hanford Site include in-stream and riparian habitats on the Columbia and Yakima rivers, Crab Creek, and shrub-steppe habitat types surrounding the Hanford Site.

The SLERA will implicitly include the special ecological areas because it will use the maximum soil or sediment and water concentrations either within the Hanford Site or the adjacent offsite area and because it will assume that all representative ecological receptors are present at each of the maximum deposition locations regardless of habitat. Therefore, ecological receptors within the special ecological areas outside the Hanford Site will have lower exposures than the receptors evaluated in the SLERA.

8.1.3 Receptor Identification

The receptors present in the ecological setting and habitats at Hanford and offsite locations will be exposed by routes that are defined by how the receptors live and what they eat. Food webs represent the transfer of matter among the components of an ecosystem. This transfer occurs through the uptake and absorption of substances from abiotic media or consumption of animal and plant tissue. Figure 8-8 shows the food web representing the terrestrial organisms and their general trophic relationships. Figure 8-9 shows the food web representing the aquatic organisms and their general trophic relationships. The food webs highlight the selected terrestrial receptors (Figure 8-8) and also aquatic receptors (Figure 8-9).

8.1.3.1 Terrestrial Receptors

Figure 8-8 presents a simplified food web for selected terrestrial receptors. The receptors selected for use in the SLERA and their trophic levels are shown in bold in the figure:

- Plants (Trophic Level 1): cheatgrass, rabbitbrush
- Terrestrial invertebrates (Trophic Level 2): earthworms, darkling beetles
- Herbivorous mammals (Trophic Level 2): mule deer
- Herbivorous birds (Trophic Level 2): mourning dove
- Omnivorous mammals (Trophic Level 3): Great Basin pocket mouse
- Omnivorous birds (Trophic Level 3): western meadowlark
- Carnivorous mammals (Trophic Level 4): coyote
- Carnivorous birds (Trophic Level 4): burrowing owl, red-tailed hawk

The reasons for selecting the representative receptors are given below. The conservative approach is to assume receptors are exposed to air, soil concentrations, and terrestrial plants at the onsite ground maximum, but are only exposed to water at the Columbia River maximum.

Terrestrial Plants. Terrestrial plants are essential to the function of any terrestrial ecosystem and are a major route of entry of contaminants into the food web; therefore, terrestrial plant populations will be evaluated in the SLERA. Terrestrial plants are assumed to be exposed to the onsite ground maximum by direct uptake of COPCs in volatile emissions, uptake of COPCs and ROPCs deposited on leaf surfaces, root uptake from soil, external exposure to radionuclides in soil, and external exposure to radionuclides in soil and air.

Terrestrial Invertebrates. Terrestrial invertebrates are essential to the function of any terrestrial ecosystem and are a major route of entry of contaminants into the food web. The number of earthworms at the Hanford Site is expected to be low because of the aridity of most of the habitat. However, there are more data available to evaluate exposure of earthworms than there is for other terrestrial invertebrates. Therefore, earthworm populations will be evaluated as representatives of terrestrial invertebrates in the SLERA. Earthworms are assumed to be exposed to the onsite ground maximum by uptake of COPCs and ROPCs deposited on soil and by external exposure to ROPCs in soil and air. There are no uptake factors for transfer of COPCs from air to terrestrial invertebrates that are separate from the experimental soil exposures used to derive the uptake factors.

Mule Deer. Mule deer populations are evaluated as representative of herbivorous mammals that consume vegetation contaminated by COPCs and ROPCs. Mule deer are assumed to be exposed by ingestion of COPCs and ROPCs deposited on soil, by ingestion of plants containing COPCs and ROPCs taken up from soil, by ingestion of surface water containing COPCs and ROPCs, and by external radiation from soil and air. The predominant diet of the mule deer is browse.

Mourning Dove. Mourning dove populations are evaluated as representative of herbivorous birds that consume vegetation contaminated by COPCs and ROPCs. The mourning dove is assumed to be exposed by ingestion of COPCs and ROPCs deposited on soil, by ingestion of plants (mainly grass seeds) containing COPCs and ROPCs taken up from soil, by ingestion of surface water containing COPCs and ROPCs, and by external radiation from soil and air.

Great Basin Pocket Mouse. Great Basin pocket mouse populations are evaluated as representative of omnivorous mammals. The Great Basin pocket mouse is assumed to be exposed by ingestion of COPCs and ROPCs deposited on soil, by ingestion of plants (mainly grass seeds) and terrestrial invertebrates containing COPCs and ROPCs taken up from soil, and by external radiation from soil and air. The mouse is assumed to get its water through food sources and thus ingestion of surface water containing COPCs and ROPCs is not applicable for the mouse.

Western Meadowlark. Western meadowlark populations are evaluated as representative of omnivorous birds. The meadowlark is assumed to be exposed by ingestion of COPCs and ROPCs deposited on soil, by ingestion of plants (mainly grass seeds) and terrestrial invertebrates containing COPCs and ROPCs taken up from soil, by ingestion of surface water containing COPCs and ROPCs, and by external radiation from soil and air.

Coyote. Coyote populations are evaluated as representative of carnivorous mammals. The coyote is assumed to be exposed by ingestion of COPCs and ROPCs deposited on soil, by ingestion of small mammals and birds containing COPCs and ROPCs taken up from soil, by ingestion of surface water containing COPCs and ROPCs, and by external radiation from soil and air.

Burrowing Owl. Burrowing owl populations are evaluated as representative of carnivorous birds. The burrowing owl is assumed to be exposed by ingestion of COPCs and ROPCs deposited on soil, by ingestion of small mammals and birds containing COPCs and ROPCs taken up from soil, by ingestion of surface water containing COPCs and ROPCs, and by external radiation from soil and air.

Red-Tailed Hawk. Red-tailed hawks are evaluated as representative of federal- and state-listed carnivorous birds of special interest, although the bird itself is not a federal- or state-listed species. The red-tailed hawk is assumed to be exposed by ingestion of small mammals and birds containing COPCs and ROPCs taken up from soil, by ingestion of surface water containing COPCs and ROPCs, and by external radiation from soil and air.

8.1.3.2 Aquatic Receptors

Figure 8-9 presents a simplified food web of selected aquatic receptors. The receptors selected for use in the SLERA are shown in bold on the figure and are listed below:

- Plants (Trophic Level 1): aquatic plants and plants rooted in sediment
- Benthic invertebrates (Trophic Level 2): sediment-dwelling clams and insects
- Aquatic organisms, fish, and other aquatic biota (Trophic Levels 2 through 4): bass, salmon, channel catfish, water fleas, other invertebrates
- Herbivorous waterfowl (Trophic Level 2): Canada goose
- Shorebirds (Trophic Level 3): spotted sandpiper
- Piscivorous birds (Trophic Level 4): great blue heron, bald eagle
- Piscivorous mammals (Trophic Level 4): mink

The reasons for selecting the representative receptors are given below. The conservative approach taken is to assume receptors are exposed to water, sediment concentrations, and aquatic plants at the Columbia River maximum, but air concentrations from the onsite maximum.

Aquatic Plants. Aquatic plants are important to the function of an aquatic ecosystem. Plankton, floating plants, and emergent plants contribute to the base of the food web. However, because of the lack of toxicity information, their risk is not quantified. They are handled as ingestion exposure to aquatic herbivores and omnivores.

Benthic Invertebrates. Benthic invertebrates are essential for the functioning of an aquatic ecosystem and are a major route of entry of contaminants into aquatic food webs. Therefore, benthic invertebrates will be evaluated in the SLERA. Benthic invertebrates are likely to be present in the Columbia River at the location of maximum deposition of COPCs and ROPCs. Benthic invertebrates are assumed to be exposed by uptake from sediment and by external radiation from water and sediment.

Aquatic Biota. Aquatic biota are essential for the functioning of an aquatic ecosystem and are a major route of entry of contaminants into aquatic food webs. Therefore, aquatic biota populations will be evaluated in the SLERA. Aquatic biota are likely to be present in the Columbia River at the location of maximum deposition of COPCs and ROPCs. Aquatic biota are assumed to be exposed by uptake from surface water, ingestion of food containing COPCs and ROPCs taken up from water, and by external radiation from water and sediment.

Salmonids. Chinook salmon and steelhead trout populations in the Hanford Reach of the Columbia

River have been designated ESUs (Neitzel et al. 2005). Therefore, special care must be taken to prevent harm to these salmonids. Salmonids are also fish species of special interest because of their economic and recreational importance and, as carnivorous fish, they are at the top of aquatic food webs. Salmonids are also of particular cultural importance to the American Indian tribes, whose way of life has inextricably included salmon and trout as food throughout their history. Therefore, salmonid populations will be evaluated in the SLERA. Salmonids are likely to be present in the Columbia River at the location of maximum deposition of COPCs and ROPCs. Salmonids are assumed to be exposed by uptake from surface water, ingestion of food containing COPCs and ROPCs taken up from water, and by external radiation from water and sediment.

Canada Goose. Canada goose populations are evaluated as representative of herbivorous birds that consume vegetation contaminated by COPCs and ROPCs from water. Because the Canada goose is a year-round resident at the Hanford Site (DOE 2001), it could be expected to spend its life at the location of maximum deposition of COPCs and ROPCs. The Canada goose is assumed to be exposed by uptake from ingested surface water and sediment, ingestion of vegetation that contains COPCs and ROPCs taken up from sediment and water, and external radiation from water and air.

Spotted Sandpiper. Spotted sandpiper populations are evaluated as representative of carnivorous birds that consume benthic invertebrates contaminated by COPCs and ROPCs from near-shore sediment. The spotted sandpiper resides along the shores of the Columbia River, where it preys on aquatic and terrestrial invertebrates and small fish. It represents the group of carnivorous shorebirds that are exposed to contaminants in aquatic biota, benthic organisms, and water. The spotted sandpiper could be expected to spend its life at the location of maximum deposition of COPCs and ROPCs. The spotted sandpiper is assumed to be exposed by uptake from ingested surface water and sediment, ingestion of benthic invertebrates that contain COPCs and ROPCs taken up from sediment, and external radiation from water and air.

Great Blue Heron. Great blue heron populations are evaluated as representative of carnivorous birds that consume small fish contaminated by COPCs and ROPCs from water. The great blue heron could be expected to spend its life at the location of maximum deposition of COPCs and ROPCs. The great blue heron is assumed to be exposed by uptake from ingested surface water, ingestion of omnivorous and planktivorous fish that contain COPCs and ROPCs taken up from water, ingestion of benthic invertebrates exposed by uptake from sediment, and external radiation from water and air.

Bald Eagle. Bald eagle populations are evaluated as representative of carnivorous birds of special interest that consume omnivorous fish contaminated by COPCs and ROPCs from water. The bald eagle is known to nest along the Columbia River, but often leaves the area before laying eggs (WHC 1994). Resident eagles are exposed to contaminants in fish as well as waterfowl, small mammals, and carrion, on which they prey. The bald eagle is the best representative of top predators of aquatic biota on the Hanford Site. For conservatism in the SLERA, the bald eagle will be assumed to be exposed year-round by ingestion of surface water, fish that contain COPCs and ROPCs taken up from water, and external radiation from water and air.

Mink. Mink populations are evaluated as representative of carnivorous mammals that consume omnivorous fish contaminated by COPCs and ROPCs from water. The mink could be expected to spend its life at the location of maximum deposition of COPCs and ROPCs. The mink is assumed to be exposed by uptake from ingested surface water, ingestion of fish that contain COPCs and ROPCs taken up from water, and external radiation from water and air.

8.1.3.3 Species Profiles

Quantitative descriptions of the receptor species are necessary to model exposure to COPCs and ROPCs. The following species profiles for mammals and birds provide the necessary quantitative information for each receptor, as well as text describing the species and its relation to the Hanford Site. Species profiles are not required for plants (cheatgrass and rabbitbrush) and terrestrial invertebrates (earthworms and darkling beetles) because exposures of these receptors are not modeled using receptor-specific parameters. Similarly, species profiles are not required for the following:

- Benthic invertebrates (clams, insects, snails, and worms)
- Planktivorous fish and small invertebrates (small carp, small northern squaw fish, small suckers, water fleas, and other invertebrates)
- Fish (bass, salmon, and channel catfish)

1 **Mule Deer (*Odocoileus hemionus*)**

Mule deer, with an onsite herd of several hundred, occur just about everywhere on the Hanford Site, but are most often found near the Columbia River. Mule deer use the islands and other riparian areas as fawning habitat. Bitterbrush provides important browse for the resident mule deer herd. Summer browse is chiefly herbaceous plants and the young shoots of woody plants, while winter browse includes twigs of woody plants and trees, including cedar, yew, aspen, willow, dogwood, juniper, and sage. Coyotes are a major predator, along with bobcats to a lesser extent. Mule deer are most active in the mornings and evenings.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	66.5	Average of males and females, north central Colorado (Sample et al. 1997)
ED	Exposure duration (longevity) (yrs)	20	(Anderson and Wallmo 1984)
HR	Home range (ha)	285	(Sample et al. 1997)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.035	Adjusted from 0.022 kg/kg BW dry weight per day (Sample et al. 1997) by assuming a 37 % moisture content in browse (Neuenschwander 1980)
F_P	Plant fraction	1	(Sample et al. 1997)
F_A	Animal fraction	0	(Sample et al. 1997)
SFr	Soil fraction	0.02	(Arthur and Alldredge 1979 in Beyer et al. 1994)
IR_w	Water ingestion rate (L/kg BW/d)	0.044	Average of mid-range values for winter and summer reported by Sample et al. (1997)

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Mourning Dove (*Zenaidura macroura*)

The mourning dove has the widest distribution of any North American game bird; it is the only species nesting in all 48 contiguous US states. During the winter it lives in small to large flocks where food is plentiful and good roosting and protective cover are available in nearby trees. The mourning dove feeds mostly on the ground in harvested crop fields, and along railroads and roadsides. About 98 % of its diet in all seasons is seeds. It eats some insects and snails, and picks up grit from gravel roads or sea beaches. It nests from southeastern Alaska to western Panama, and it winters from southern Canada, but mainly from northern California, south into Central America.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.128	Numerical average of males and females (Martin and Nelson 1952 in Terres 1980)
ED	Exposure duration (longevity) (yrs)	19.3	(Carey and Judge 2001)
HR	Foraging distance (km)	≤ 1	(CDFG 2003)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.212	Calculated by allometric equation, $0.398 \times BW(g)^{0.85}/BW(g)$ (EPA 1993a, Eq. 3-4), adjusted to wet-weight basis by assuming a water content of 9.3 % for seeds (EPA 1993a, Table 4-2): 0.192 / (1-0.093) = 0.212
F_P	Plant fraction	1	Diet stated to be >98 % seeds and other vegetation (Terres 1980)
F_A	Animal fraction	0	<2 % invertebrates (Terres 1980)
SFr	Soil fraction	0.09	Assumed to be 10 % of dry weight of diet (EPA 1999) : 0.1 × (1 – 0.093) = 0.09
IR_w	Water ingestion rate (L/kg BW/day)	0.116	Calculated by using allometric equation, $0.059 \times BW\ (kg)^{0.67}/BW(kg)$ [EPA 1993a, Eq. 3-15]

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Great Basin Pocket Mouse (*Perognathus parvus*)

The Great Basin pocket mouse eats mostly seeds, but also eats insects (Fitzner and Gray 1991). It is the principal prey of the burrowing, great horned, long-eared, and barn owls at the Hanford Site (Downs et al. 1993) and serves as a vector for contaminant movement through the food chain. The Great Basin pocket mouse is a nocturnal, burrowing mammal, with most burrows being between 35 cm and 193 cm (1.2 ft to 6.3 ft) deep (Gano and Rickard 1982). The mouse has no need for drinking water, obtaining all its water from its food. Its small home range could cause it to spend all of its time within a contaminated area and obtain all food there (DOE 1999).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.016	Average, males and females, Washington State (Sample et al. 1997)
ED	Exposure duration (longevity) (yrs)	8.0	Value for pocket mouse (*Perognathus spp.*) (Carey and Judge 2001)
HR	Home range (ha)	0.14	Mid-range for females, Washington State (Sample et al. 1997)
TUF	Temporal use factor	1	(DOE 1999)
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.285	(Calder 1984 in DOE-RL 1995)
F_P	Plant fraction	0.62[b]	Annual average (based on four seasons normalized to 100% and then averaged), Colorado, short-grass prairie (EPA 1993a)
F_A	Animal fraction	0.38[b]	Annual average, Colorado, short-grass prairie (EPA 1993a)
SFr	Soil fraction	0.01	Estimated 2 % of dry weight of diet (Beyer et al. 1994). Dry weight is estimated to be 57 % of a mixed diet of 55 % seeds with 9.3 % water content and 45 % terrestrial invertebrates with 84 % water content (EPA 1993a, Tables 4-1 and 4-2).
IR_w	Water ingestion rate (L/kg BW/d)	0.0	(Price 1983)

[a] Food ingestion rate (g/g/d) expressed as kg/kg BW/d does not include ingested soil; therefore, $F_P + F_A = 1.0$.
[b] Values used for the Great Basin pocket mouse taken from values established for the deer mouse (*Peromyscus maniculatus*). (Flake 1973 in EPA 1993a)

Western Meadowlark (*Sturnella neglecta*)

The western meadowlark is a ground-nesting bird that nests in cheatgrass and sagebrush-bunchgrass communities (Rickard et al. 1988, Schuler et al. 1988). The western meadowlark is a common, omnivorous bird of open habitats in southeastern Washington State and is abundant in the shrub-steppe ecosystem (Schuler et al. 1988). It feeds on a variety of items, which include both insects and plant material, mostly seeds. One study (Bent 1958 in Sample et al. 1997) reports that the western meadowlark's diet consists of roughly 70 % insects and 30 % plant material. Studies conducted in southeastern Washington State indicate that it is the main bird prey item in the diets of the red-tailed, ferruginous, and Swainson's hawks (Rickard et al. 1988). Adult female western meadowlarks average 94.2 grams in weight and lay three to seven eggs in dome-shaped nests concealed in the grass or weeds.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.094	Adult female, Washington State (Sample et al. 1997)
ED	Exposure duration (longevity) (yrs)	10.0	Value for captive species (Carey and Judge 2001)
HR	Home range (ha)	3.0	Adult male, Wisconsin, average (Sample et al. 1997)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.028	(Sample et al. 1997)
F_P	Plant fraction	0.30	(Bent 1958 in Sample et al. 1997)
F_A	Animal fraction	0.70	(Bent 1958 in Sample et al. 1997)
SFr	Soil fraction	0.04	Estimated 10.4 % of dry weight of diet of woodcock (Beyer et al. 1994) was used for the meadowlark. Dry weight is estimated to be 38 % of a mixed diet of 30 % seeds with 9.3 % water and 70 % terrestrial invertebrates with 84 % water content (EPA 1993a, Tables 4-1 & 4-2).
IR_w	Water ingestion rate (L/kg BW/d)	0.13	Calculated using allometric equation, $0.059 \times BW(kg)^{0.67}/BW(kg)$ [EPA 1993a, Eq. 3-15]

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore $F_P + F_A = 1.0$.

Coyote (*Canis latrans*)

The coyote is the most common carnivore on the Hanford Site. They are nocturnal but may be active at any time of day. Primarily carnivorous, coyotes feed mainly on birds and small mammals, but also feed on insects and fruits in season. The typical hunting range is 10 miles, but may extend to 100 miles, reflecting the coyote's variable home range. Being an upper-trophic-level receptor, the coyote could be particularly susceptible to chemicals that bioaccumulate. Coyotes living in the shrub-steppe feed on pocket mice, northern pocket gopher, Nuttall's cottontail, black-tailed jackrabbit, and occasionally small mule deer. Favored den sites are riverbanks and the sides of canyons or gulches.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	12.4	Average of adult male and female from Iowa (Sample et al. 1997)
ED	Exposure duration (longevity) (yrs)	21.8	Value for captive species (Carey and Judge 2001)
HR	Home range (ha)	3010	Living singly or in pairs (Sample et al. 1997)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.018	Desert coyote adults (Sample et al. 1997)
F_P	Plant fraction	0.02	Average for western states (Sample et al. 1997)
F_A	Animal fraction	0.98	Average for western states (Sample et al. 1997)
SFr	Soil fraction	0.002	Estimated soil ingestion rate divided by food ingestion rate
IR_w	Water ingestion rate (L/kg BW/d)	0.077	Estimated (Sample et al. 1997) by using allometric equation, $0.099 \times BW(kg)^{0.90}/BW(kg)$ [EPA 1993a, Eq. 3-17]

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Burrowing Owl (*Athene cunicularia*)

The burrowing owl is the most abundant of the owls that nest on the Hanford Site. Burrowing owls nest in holes in the ground that are abandoned by burrowing mammals. Their diet consists of pocket mice, deer mice, pocket gophers, mountain voles, black-tailed jackrabbits, Nuttall's cottontail, rock doves, mallards, and American coots.

The burrowing owl is more diurnal than most owls. The female lays five to seven eggs in a long, underground burrow lined with grasses, roots, and dung. The burrows are usually abandoned prairie dog or pocket gopher burrows, but burrowing owls are capable of digging their own.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.15	Mean, males and females, throughout North America (Sample et al. 1997)
ED	Exposure duration (longevity) (yrs)	8.7	(Carey and Judge 2001)
HR	Home range (ha)	241	Mean, Saskatchewan (Sample et al. 1997)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.042	Estimated (Sample et al. 1997) from reported energy requirement, average of winter and summer
F_P	Plant fraction	0	Colorado (Sample et al. 1997)
F_A	Animal fraction	1	Colorado (Sample et al. 1997)
SFr	Soil fraction	0.1	Estimated from mean of 5 % of volume (Thomsen 1971 in Sample et al. 1997)
IR_w	Water ingestion rate (L/kg BW/d)	0.11	Estimated (Sample et al. 1997) by using allometric equation, $0.059 \times BW (kg)^{0.67}/BW(kg)$ [EPA 1993a, Eq. 3-15]

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Red-Tailed Hawk (*Buteo jamaicensis*)

The red-tailed hawk may be found on the Hanford Site year-round (Fitzner and Gray 1991). Forty-one nesting pairs of hawks (red-tailed, Swainson's, and ferruginous) were observed on site during the 1994 breeding season (Neitzel et al. 2005). Nests were constructed in trees, cliffs, basalt outcrops, and high-voltage transmission line towers (Neitzel et al. 2005). The red-tailed hawk is a diurnal predator of rodents and other small mammals, including mice, shrews, voles, rabbits, and squirrels. Generally opportunistic, the red-tailed hawk feeds on whatever is most abundant and readily available. Red-tailed hawks maintain a territory year-round (Brown and Amadon 1968).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	1.06	Average of adult male and female, southwest Idaho (Steenhof 1983 in EPA 1993a)
ED	Exposure duration (longevity) (yrs)	18	(Henny and Wight, 1970, 1972 in EPA 1993a)
HR	Home range (ha)	1,770	Adult, both male and female, Colorado upland prairie (Andersen and Rongstad 1989 in EPA 1993a)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.105	Average of adult male and female, winter, Michigan, captive, outdoors (Craighead and Craighead 1956 in EPA 1993a)
F_P	Plant fraction	0	Not stated in EPA 1993a; assumed to be negligible
F_A	Animal fraction	1	Prey brought to nests in Alberta, Canada, Oregon, and California (EPA 1993a)
SFr	Soil fraction	0	Not stated in EPA (1993a) or Beyer et al. (1994); assumed to be negligible
IR_w	Water ingestion rate (L/kg BW/d)	0.057	Average of adult male and female rates (EPA 1993a) estimated using the allometric equation, $0.059 \times BW(kg)^{0.67}$ /BW(kg) [EPA 1993a, Eq. 3-15]

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Canada Goose (*Branta canadensis*)

Canada geese forage primarily in open fields, feeding on grains, grass sprouts, and some aquatic vegetation. Breeding habitats include tall grass prairies and shortgrass prairies, marshes, ponds, and lakes. Most nesting sites are close to open water, often on islands (EPA 1993a). The Canada goose uses islands along the Hanford Reach extensively for nesting. Studies on the nesting habits of geese that use the Hanford Site have been ongoing since 1953. These studies indicate a general decline over the years in numbers of nests on islands in the Hanford Reach because of heavy predation by coyotes (Cushing et al. 1995).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	3.72	Average of adult male and female, Nova Scotia (EPA 1993a)
ED	Exposure duration (longevity) (yrs)	24.3	(Carey and Judge 2002)
HR	Home range (ha)	983	Adult female and brood, Washington State (EPA 1993a)
TUF	Temporal use factor	1	Considered a year-round resident at the Hanford Site (DOE 2001)
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.031	Average of adult male and female, winter and spring, British Columbia interior (EPA 1993a)
F_P	Plant fraction	1	North Carolina, lake; and Ontario, bay (EPA 1993a)
F_A	Animal fraction	0	< 1 % invertebrates (EPA 1993a)
SFr	Sediment fraction	0.07	Estimated 8.2 % of dry weight of diet (Beyer et al. 1994). Dry weight is estimated to be 0.89 × wet weight for grain and seeds (EPA 1993a).
IR_W	Water ingestion rate (L/kg BW/d)	0.038	Average of adult male and female, estimated (EPA 1993a) by using allometric equation, $0.059 \times BW(kg)^{0.67}/BW(kg)$ (EPA 1993a, Eq. 3-15)

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Spotted Sandpiper (*Actitus macularia*)

The spotted sandpiper requires open water for drinking, semi-open habitat for nesting, and dense vegetation for breeding (Bent 1929 and Oring et al. 1983 in EPA 1993a). The nest is a grassy scrape near water or in brush with a determinate clutch size of four eggs. Several clutches may be laid during a given breeding season. The diet of the spotted sandpiper consists mostly of terrestrial and aquatic insects (Bent 1929 in EPA 1993a), with adult flying insects making up the bulk of the diet (Oring et al. 1983 in EPA 1993a).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.0425	Arithmetic mean, adult, males and females, Minnesota (EPA 1993a)
ED	Exposure duration (longevity) (yrs)	3.7	(Oring et al., 1983 in EPA 1993a)
HR	Home range (ha)	0.25	Single value, sex not specified, Nova Scotia (EPA 1993a)
TUF	Temporal use factor	1	Will be 1 unless a specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.88	Calculated by allometric equation, $0.648 \times BW(g)^{0.651}/BW(g)$ (EPA 1993a, Eq. 3-3), adjusted to wet- weight basis by assuming food moisture content of 80 % for benthic invertebrates (EPA 1993, Table 4-1). $IR_F = 0.175 / (1\text{-}0.8) = 0.88$
F_P	Plant fraction	0	None listed as dietary intake in EPA (1993a)
F_A	Animal fraction	1	Benthic invertebrates, Minnesota, lake (EPA 1993a)
SFr	Sediment fraction	0.036	Estimated 18 % of dry weight of diet (Beyer et al. 1994). Dry weight is estimated to be 0.2 × wet weight for benthic invertebrates (EPA 1993a, Table 4-1). SFr = 0.18 × 0.2 = 0.036.
IR_W	Water ingestion rate (L/kg BW/d)	0.165	Average of adult male and female rates (EPA 1993a), estimated by using allometric equation, $0.059 \times BW(kg)^{0.67}/BW(kg)$ (EPA 1993a, Eq. 3-15)

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Great Blue Heron (*Ardea herodius*)

Great blue herons are year-round residents of the Hanford Reach. This bird is relatively common along the Hanford Reach (Fitzner and Gray 1991). Some of the trees planted on pre-1943 farms have persisted and serve as nesting platforms for several species of birds, including the great blue herons (DOE-RL 1995). Its nest is a platform of sticks lined with finer material and is sometimes found on the ground or in a reedbed. Principal prey items of the great blue heron are fish and frogs, although it will also feed on small mammals, reptiles, and occasionally birds.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	2.39	Arithmetic mean, adult, both sexes, location not stated (EPA 1993a)
ED	Exposure duration (longevity) (yrs)	23.3	(Carey and Judge 2001)
HR	Foraging range (km)	3.1	Foraging distance, mean, adults, both sexes, South Dakota, stream (EPA 1993a)
TUF	Temporal use factor	1	Will be 1 unless a specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.18	(EPA 1993a)
F_P	Plant fraction	0	None listed as dietary intake in EPA (1993a)
F_A	Animal fraction	1	98 % aquatic vertebrates, a river in lower Michigan (EPA 1993a)
SFr	Sediment fraction	0	Not reported in EPA (1993a); assumed to be negligible
IR_W	Water ingestion rate (L/kg BW/d)	0.045	Estimated (EPA 1993a) by using allometric equation, $0.059 \times BW(kg)^{0.67}/BW\ (kg)$ (EPA 1993a, Eq. 3-15)

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Bald Eagle (*Haliaetus leucocephalus*)

The bald eagle is a common winter resident, usually arriving in October. These birds forage throughout the Hanford Reach. Bald eagles use trees during the day for perching and occasionally at night for communal roosts (DOE 1999). Wintering eagles tend to concentrate where food is abundant and human disturbance is minimal. The diet of bald eagles varies locally as well as seasonally. Food may vary from spawned salmon and waterfowl (often killed by other predators or disease) during the winter to fish, small mammals, carrion, and waterfowl during the breeding season (EPA 1993a). Although bald eagles exhibit nesting behavior at the Hanford Site, most leave before laying eggs (WHC 1994).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	3.75	Arithmetic mean, adult, both sexes, Florida (EPA 1993a)
ED	Exposure duration (longevity) (yrs)	50	(Snow, 1973 in EPA 1993a)
HR	Foraging distance (km)	10	Territory length, mean, adults, coastal Washington State (EPA 1993a)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.12	Adult, both sexes, Washington State, free-flying (EPA 1993a)
F_P	Plant fraction	0	None listed as dietary intake in EPA (1993a)
F_A	Animal fraction	1	53 % birds, 27 % fish, 20 % other, Washington State, river (EPA 1993a)
SFr	Sediment fraction	0	Not reported in EPA 1993a; assumed to be negligible
IR_W	Water ingestion rate (L/kgBW/d)	0.036	Average of adult male and female rates, estimated (EPA 1993a) by using allometric equation, $0.059 \times BW(kg)^{0.67}/BW\ (kg)$ (EPA 1993a, Eq. 3-15)

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

Mink (*Mustela vison*)

The mink is the most abundant and widespread carnivorous mammal in North America. The home range of mink encompasses both their foraging areas around waterways and their dens along the Columbia River. The mink is found in aquatic habitats of all kinds, including waterways such as rivers, streams, lakes, and ditches, as well as swamps, marshes, and backwater areas (Linscombe et al. 1982 in EPA 1993a). Mink are particularly sensitive to certain chemicals. Mink are predominantly nocturnal hunters, although they are sometimes active during the day. They can often be found along the Columbia River. Mammals are the mink's most important prey year-round in many parts of their range (Eagle and Whitman 1987 in EPA 1993a), but mink also hunt aquatic prey (such as fish, amphibians, and crustaceans) and other terrestrial prey (such as birds, reptiles, and insects) depending on the season (Linscombe et al. 1982 in EPA 1993a). Salmon and trout can outmaneuver them, unless the fish are preoccupied with spawning (Eaton 2009).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.85	Average of adult male and female (summer and fall) (EPA 1993a)
ED	Exposure duration (longevity) (yrs)	11	Value for captive species (Enders, 1952 in EPA 1993a)
HR	Foraging distance (km)	2.24	Foraging distance, mean, adults, both sexes, Sweden/stream (EPA 1993a)
TUF	Temporal use factor	1	Will be 1 unless specific value exists for a receptor
IR_F	Food ingestion rate (g/g/d = kg/kg BW/d)[a]	0.14	Michigan (farm raised) (EPA 1993a)
F_P	Plant fraction	0.09	Michigan/stream, river (% wet wt; stomach contents normalized to 97.5% of contents identified) (EPA 1993a)
F_A	Animal fraction	0.91	Michigan/stream, river (% wet wt; stomach contents normalized to 97.5% of contents identified) (EPA 1993a)
SFr	Sediment fraction	0	(Sample et al. 1997)
IR_W	Water ingestion rate (L/kgBW/d)	0.11	Estimated (EPA 1993a) by using allometric equation, $0.099 \times BW(kg)^{0.90}/BW\ (kg)$ (EPA 1993a, Eq. 3-17)

[a] Food ingestion rate (g/g/d) re-expressed as kg/kg BW/d is assumed not to include ingested soil; therefore, $F_P + F_A = 1.0$.

8.1.4 Assessment Endpoints

An assessment endpoint is defined by EPA (1997) to be "an expression of an ecological attribute that is to be protected." Environmental statutes govern the protection of ecological resources, including:

- Preservation and conservation of T&E organisms
- Maintenance and protection of terrestrial organism populations and ecosystems
- Maintenance and protection of aquatic organism populations and ecosystems

To fulfill these requirements, the assessment endpoints were chosen to:

- Protect and conserve individuals and populations of T&E species (Table 8-2, assessment endpoint 1).
- Maintain and protect terrestrial populations and ecosystems, including plants (Table 8-2, assessment endpoint 2), invertebrates (Table 8-2, assessment endpoint 3), herbivorous animals (Table 8-2, assessment endpoint 4), omnivorous animals (Table 8-2, assessment endpoint 5), and terrestrial predators (Table 8-2, assessment endpoint 6).
- Maintain and protect aquatic populations and ecosystems, including sediment-dwelling organisms (Table 8-2, assessment endpoint 7), planktivorous fish and small aquatic invertebrates (Table 8-2, assessment endpoint 8), waterfowl (Table 8-2, assessment endpoint 9), large carnivorous fish (Table 8-2, assessment endpoint 10), and fish-eating predators (Table 8-2, assessment endpoint 11).

The assessment endpoints reflect the conceptual exposure model and are based on the identified receptors and their recognized complete exposure pathways. Critical attributes of identified ecological receptors (population, community, or individual in the case of T&E species) are abundance and productivity, which are functions of survival and reproduction. Protection of receptors' survival and reproduction is assumed to protect the structure and function of the local ecosystem (EPA 1999). Measures of effect are defined as measures of change in critical attributes in response to a stressor to which receptors are exposed. For the Hanford Site risk assessment, modeled exposure concentrations and doses are compared to published concentrations and doses associated with measures of toxicological effect on the identified receptors or related species. Decision criteria prescribe how the endpoints are evaluated using the measures of effect.

Policy goals, assessment endpoints, measures of effect, and decision rules used for the SLERA are presented in Table 8-2.

8.2 Exposure Assessment

Estimation of the risk to ecological receptors from COPCs and ROPCs in environmental media at an exposure location requires an estimate of exposure and a toxicity reference value (*TRV*) (i.e., an exposure level associated with little or no adverse effect). Section 8.3 discusses *TRV*s. This section describes how the exposures of ecological receptors are estimated for environmental media at the WTP exposure locations. Exposure locations at the Hanford Site are areas within the deposition grid at which ecological receptors come into contact with COPCs and ROPCs in media contaminated by stack emissions. Contamination at a given location is represented by modeled concentrations of COPCs and ROPCs in environmental media. Receptor locations and emissions data used to compute EPCs are the same as in the human health risk assessment, but are limited to the onsite ground maximum (terrestrial receptors) and Columbia River maximum (aquatic receptors and all water consumption). This approach ensures that a conservative risk assessment results, since exposure at any other location would be lower. If there are no unacceptable risks at the points of maximum deposition and air concentration, logically there cannot be unacceptable risks at other locations where COPC and ROPC concentrations are lower. Therefore, additional information about exposure at points with lower soil, air, or water concentrations will not be necessary.

The exposure assessments for ecological receptors estimate the exposure from ingestion of food and environmental media containing COPCs and ROPCs under certain assumptions. The ingestion rates of food and environmental media (soil, sediment, and water) and the proportions of different types of food that WTP receptors realistically ingest are given in Section 8.1 of this work plan. The proportions of different types of food that a receptor ingests (i.e., its diet) are an important factor in determining the exposure because different food types have different uptake rates of COPCs and ROPCs and, therefore, different concentrations in tissues. The diets to be used for the SLERA are defined in Section 8.2.1.

The assessment of exposure for ecological receptors requires estimates of the EPCs of COPCs and ROPCs in environmental media, including plants and animals ingested by receptors. Section 8.2 discusses EPCs. The SLERA will use modeled whole-body concentrations in food items to estimate doses to wildlife receptors. All terrestrial receptors are assumed to be exposed to the calculated concentrations of contaminants at the ground maximum or Columbia River maximum, regardless of the likelihood that they occur there.

The equations to be used to estimate exposure for terrestrial and aquatic receptors at the WTP exposure locations are described below (Sections 8.2.3 and 8.2.4). Two types of exposure estimates are required:

- The exposure estimate for receptors living immersed in a medium containing COPCs or ROPCs (such as vegetation and terrestrial invertebrates living in soil, fish and other aquatic life living in surface water, and benthic organisms living in sediment) is the concentration of COPC or ROPC in the medium.
- The exposure estimate for a wildlife receptor that does not live in a medium containing COPCs or ROPCs but is exposed by ingestion is the estimated daily dose (*DD*).

The exposure equations for wildlife are variations of wildlife exposure equations from EPA 1999 and implied in other sources (EPA 1997, 1998). These equations are used to calculate both the concentrations of COPCs and ROPCs in the tissues of receptors that are used for food (and in the case of ROPCs, the tissues of all other wildlife receptors) and the ingested doses of COPCs and ROPCs. The equations for ecological receptors are functionally equivalent to the equations in Section 7.1 of this work plan that are used to quantify exposure of humans by ingestion of contaminated food (EPA 2005). All ingested dose equations calculate the amount of contaminant ingested per unit biomass per unit time by multiplying the concentration of the contaminant in the ingested medium (abiotic medium or food item) by the receptor's ingestion rate for that medium and dividing by the receptor's body weight. The wildlife equations allow for the contaminant concentration in a food item to be calculated as the product of the contaminant concentration in an abiotic medium and the bioaccumulation (uptake or transfer) factor for the medium.

The modeled whole-body concentrations of contaminants in plants and fish consumed by both humans and nonhuman receptors will be calculated by using bioaccumulation factors, ingestion rates, and other parameters (Section 8.2.5) in model equations described by EPA (1999). The SLERA will use these modeled whole-body concentrations to estimate doses to wildlife receptors.

The diets to be used in the PRA and the FRA for WTP receptors are discussed in the following subsection.

8.2.1 Diet

The proportions of different types of food that a receptor eats (i.e., its diet) are important factors in determining the exposure because different food types have different concentrations of COPCs and ROPCs. Two general types of diet by which ingestion exposure of omnivores and carnivores can be estimated are discussed in this section. An *exclusive diet* is a diet consisting of a single type of prey or food, and a *realistic diet* is a diet where the fractions of different types of prey or food eaten are more or less the fractions reported to actually occur in one or more cases for the receptor or similar species. In the PRA and in the FRA, the exposure assessment will evaluate an exclusive diet in which the concentration of COPC or ROPC is calculated for each food item, and the higher concentration is used in the exposure evaluation. The exclusive-diet scenario will be evaluated as a worst-case scenario (i.e., it gives the most conservative risk estimate). If use of the exclusive diet results in an $HI > 0.25$ for an omnivore or one of its predators, exposure will be reevaluated using realistic diets subject to Ecology approval. In general, the fractions of prey or food types in a given animal's diet, the body burdens in each prey or food type, and the animal's bioconcentration factor (*BCF*) for the COPC or ROPC determines the animal's body burden and, thus, the exposure of its predator.

For 12 of the WTP receptors, a diet must be specified to quantify the dose of COPCs and ROPCs resulting from ingested food. Three of the receptors (mule deer, mourning dove, and Canada goose) eat only plants; four of the receptors (red-tailed hawk, spotted sandpiper, great blue heron, and bald eagle) eat only animals; the remaining five receptors (Great Basin pocket mouse, Western meadowlark, burrowing owl, coyote, and mink) typically eat a mixed diet of both plants and animals. However, the typical plant fraction for burrowing owl, coyote, and mink is so small that they will be evaluated as strict carnivores. An exclusive diet will be used for each of the omnivores and carnivores. Use of the realistic diet would reduce the ingestion exposure of mice and meadowlarks. It would also reduce the tissue concentrations in mice and meadowlarks and, thereby, reduce the ingestion exposure of the terrestrial carnivores—coyotes, owls, and hawks.

For the omnivores (pocket mouse and western meadowlark) and the top predators (coyote, burrowing owl, and red-tailed hawk), the SLERA will evaluate only the exclusive diet comprising the food type with the higher concentration for a given COPC. For the omnivores, if the plant food has the higher concentration for a given COPC, then the diet of 100 % plants will be evaluated (Figure 8-10), and vice versa should the food of the soil-dwelling invertebrate have higher tissue concentration. In this way, the exclusive diet will bound risk associated with insectivores as well as strict herbivores. For the top predators, if the small mammal prey (pocket mouse) has the highest concentration for a given COPC, then the diet of 100 % pocket mice will be evaluated (Figure 8-11), and vice versa should the western meadowlark have the higher tissue concentration. For mink, the SLERA will evaluate a diet of 100 % fish. This approach always results in the most conservative, highest exposure estimate for a given COPC for omnivores (pocket mouse and meadowlark) and predators (coyote, owl, hawk, and mink) that eat multiple types of food. For ROPCs, the assessment will evaluate only the exclusive diet of the food type resulting in the higher tissue concentration in the receptor.

If use of the exclusive diet results in an $HI > 0.25$ for an omnivore or one of its predators, exposure will be reevaluated using realistic diets subject to Ecology approval.

Concentrations used to estimate exposure for ecological receptors, exposure equations for terrestrial and aquatic receptors, and the variables and parameters used in these equations to estimate exposures for ecological receptors are provided in the following sections.

8.2.2 Exposure Point Concentrations in Abiotic Media

Exposure of ecological receptors to COPCs and ROPCs in this work plan will be estimated from the concentrations predicted by the aerial dispersion and other fate and transport models (Section 6). Dispersion model output concentrations will be used to calculate exposure concentrations for gases and particulates in air ($\mu g/m^3$, pCi/m^3) and surface soil (mg/kg, pCi/g) at the onsite ground maximum, and gases and particulates in air ($\mu g/m^3$, pCi/m^3), surface water (mg/L, pCi/L), and sediment (mg/kg, pCi/g) at the Columbia River maximum. For each of these exposure locations on the dispersion grid, the modeled concentration will be used to estimate the exposure to terrestrial (Section 8.2.3) and aquatic (Section 8.2.4) ecological receptors as appropriate. Use of maximum-modeled concentrations represents a conservative estimate of potential exposure due to the WTP operations.

In keeping with the protective approach that will be used in the SLERA, EPCs used to estimate doses of COPCs and ROPCs for the quantitative SLERA will correspond to the maximum concentrations at the locations of maximum deposition, and potential exposure to all ecological receptors will be evaluated there.

8.2.3 Quantification of Exposure (Terrestrial Receptors)

Quantifying exposures for receptors exposed by direct contact with air and soil, and ingestion of soil and biota, requires the EPCs of COPCs and ROPCs in air, soil, and biota. The method for calculating EPCs in air and soil is described in Section 8.2.2. The EPCs of COPCs and ROPCs in biota (Section 8.2.3.1) are required in order to calculate the *DD* by ingestion (Sections 8.2.3.2 and 8.2.3.3) and the internal radiation dose for wildlife receptors (Section 8.2.3.4).

Terrestrial receptors at Hanford can find water in many sources, including rain, snow, dew, and incidental surface sources. However, climate in the region results in greater evapotranspiration than precipitation (DOE 1997). Therefore, most potential water sources are ephemeral and are not appropriate for deposition modeling, which assumes a 40-year accumulation of COPCs and ROPCs. It is assumed for the RAWP that the terrestrial receptors ingesting surface water do so at the Columbia River maximum location. Exposure by ingestion of drinking water will also be evaluated for aquatic receptors at the Columbia River maximum location, where the river is also the source of drinking water for Canada goose, spotted sandpiper, great blue heron, bald eagle, and mink.

8.2.3.1 EPCs in Terrestrial Biota

Calculating EPCs for tissues of terrestrial plants and animals exposed by direct contact with air and soil requires the EPCs of COPCs and the ROPCs in air (C_a) and soil (Cs) and the receptor bioaccumulation and uptake factors for the COPCs and ROPCs (Section 8.2.5.3). The remaining EPCs for receptors are computed using methodology from the SLERAP. Unless specifically stated otherwise, all tissue and body weights are wet or fresh weights (FW), whereas soil weights are dry weights (DW).

EPCs in Terrestrial Plants (Trophic Level 1)

The EPC for terrestrial plants (C_{TP}) exposed to COPCs and ROPCs in air and surface soil and fed upon by herbivores and omnivores is given by:

$$C_{TP} = Pd + Pv + Pr \qquad \text{(SLERAP Eq. 5-6)}$$

where:

C_{TP}	=	concentration of COPC or ROPC in plant tissue (mg/kg or pCi/g)
Pd	=	concentration resulting from uptake from particles deposited on leaf surfaces (mg/kg or pCi/g)
Pv	=	concentration resulting from uptake of vapors by direct contact with air (mg/kg or pCi/g)
Pr	=	concentration resulting from uptake from soil through roots (mg/kg or pCi/g)

Equations for the calculation of Pd and Pv are presented in Sections 6.6.1 and 6.6.2, respectively. Pr is calculated as:

$$Pr = Cs_{15} \times BCF_r \times 0.12 \qquad \text{(SLERAP Table B-3-3)}$$

where:

Pr	=	concentration resulting from uptake from soil through roots (mg/kg or pCi/g)
Cs_{15}	=	concentration of constituent in soil (mg/kg or pCi/g), based upon a 15 cm root-zone soil depth
BCF_r	=	plant-soil biotransfer factor (mg/kg DW plant per mg/kg DW soil)
0.12	=	dry-weight to wet-weight conversion (unitless, EPA 1999)

The values of BCF_r are discussed in Section 8.2.5.3. Values of BCF_r for all COPCs and ROPCs are reported in Supplement 4.

EPCs in Terrestrial Invertebrates (Trophic Level 2)

For terrestrial invertebrates exposed to COPCs and ROPCs in air and surface soil and fed upon by omnivores, the tissue EPC will be calculated by using either a measured soil-to-invertebrate uptake factor or a calculated soil porewater concentration and an empirically determined water-to-invertebrate uptake factor. The EPCs for COPCs and ROPCs with measured uptake factors are calculated in accordance with EPA (1999) draft guidance:

$$C_{INV} = Cs_{15} \cdot BCF_S \qquad \text{(SLERAP Table F-1-3)}$$

where:

C_{INV}	=	fresh weight concentration of COPC or ROPC in animal tissue (mg/kg or pCi/g)

Cs_{15} = concentration of COPC or ROPC in soil (mg/kg or pCi/g), based upon a 15 cm soil depth

BCF_S = soil-to-invertebrate uptake factor (mg/kg FW tissue per mg/kg DW soil)

The values of BCF_S are discussed in Section 8.2.5.3. Values of BCF_S for all COPCs and ROPCs are reported in Supplement 4.

For many organic COPCs, measured BCF_S values are not available. Instead, per EPA draft guidance (EPA 1999), values of BCF_S for organic COPCs for which no measured values were available were calculated with an equation (SLERAP Eq. C-1-1) derived by regression analysis of uptake of several organic chemicals from water by aquatic invertebrates as a function of log K_{ow} (Southworth et al., 1978 [see Section 8.2.5.3 for further discussion of the equation]). K_{ow} is the ratio of the molar concentrations (in a dilute solution) of a chemical in n-octanol and in water. Since K_{ow} is the ratio of two molar concentrations, it is a dimensionless quantity. Sometimes K_{ow} is reported as the decadic logarithm (log K_{ow}). K_{ow} provides a measure of chemical lipophilicity, that is, the degree to which a chemical dissolves in a lipid (an oily compound). The K_{ow} values for affected organic COPCs are wide-ranging. Based on the equilibrium partitioning approach described in EPA (SLERAP Section 5.3.2.1), BCF_W values for COPCs with higher log K_{ow} values will be used with estimated soil porewater concentrations, rather than soil concentrations, to estimate COPC concentrations in terrestrial invertebrates.

$$\log BCF_W = 0.819 \cdot \log K_{ow} - 1.146 \qquad \text{(SLERAP Eq. C-1-4)}$$

where:

BCF_W = water-to-tissue uptake factor for terrestrial invertebrates (mg/kg FW tissue per mg/L water)

K_{ow} = octanol-water partition coefficient of the compound (unitless)

To be taken up by terrestrial invertebrates, chemicals must be in solution in soil porewater. For most organic COPCs, only a small fraction of the COPC in soil is dissolved in porewater, and the biologically available fraction of these organic COPCs in soil (i.e., the fraction in soil porewater) is small. Chemicals in soil porewater are assumed to be in equilibrium with chemicals bound to soil particles. The ratio of concentration in soil porewater to concentration on soil particles is given by the partitioning coefficient (Kd_s) that is characteristic of the chemical and the soil. However, most organic COPCs in soil are bound to organic carbon rather than to the mineral structure of soil particles (EPA 1993b), and Kd_s is not constant for soils with different organic carbon contents. A more useful partitioning coefficient is the ratio of the concentration relative to soil carbon (mg/kg carbon) to the concentration in soil porewater (mg/L) and is designated K_{oc}. K_{oc} can be multiplied by the fraction of organic carbon in the soil to derive the porewater-to-soil concentration ratio:

$$Kd_s = K_{oc} \cdot f_{oc} \qquad \text{(SLERAP Eq. A-2-8a)}$$

where:

Kd_s = soil-water partitioning coefficient (L/kg soil)

K_{oc} = soil organic carbon-water partitioning coefficient (L/kg carbon)

f_{oc} = fraction of soil that is organic carbon, 0.0044 (fraction of organic carbon in soil, site-specific value from average organic carbon measurements in Paragon Analytics, Inc., CCN 150854) (kg carbon/kg soil)

The concentration in interstitial water (C_{IW}) can be calculated by dividing the concentration in the media of interest (Cs_{15}) by Kd_s:

$$C_{IW} = \frac{Cs_{15}}{Kd_s}$$

and by substitution (as shown in Eq. 5-5 of EPA draft guidance [EPA 1999]):

$$C_{IW} = \frac{Cs_{15}}{K_{oc} \cdot f_{oc}} \qquad \text{(SLERAP Eq. 5-5)}$$

where:

C_{IW} = concentration of organic COPC in soil interstitial water (mg/L)
Cs_{15} = concentration of organic COPC in soil (mg/kg soil), based upon a 15 cm soil depth
K_{oc} = soil organic carbon-water partitioning coefficient (L/kg carbon)
f_{oc} = fraction of soil that is organic carbon, 0.0044 (fraction of organic carbon in soil, site-specific value from average organic carbon measurements in Paragon Analytics, Inc., CCN 150854) (kg carbon/kg soil)

Thus, the tissue EPC for organic COPCs derived by using the calculated BCF_W would be:

$$C_{INV} = C_{IW}.BCF_W \qquad \text{(SLERAP Eq. 5-4)}$$

and:

$$C_{INV} = \frac{Cs_{15}}{f_{oc} \cdot K_{oc}} \cdot BCF_W$$

where:

C_{INV} = concentration of organic COPC in animal tissue (mg/kg)
C_{IW} = concentration of organic COPC in soil porewater (mg/L)
BCF_W = water-to-tissue uptake factor for terrestrial invertebrates (mg/kg FW tissue per mg/L water)
Cs_{15} = concentration of organic COPC in 15 cm root-zone depth soil (mg/kg)
f_{oc} = fraction of soil that is organic carbon, 0.0044 (fraction of organic carbon in soil, site-specific value from average organic carbon measurements in Paragon Analytics, Inc., CCN 150854) (kg carbon / kg soil)
K_{oc} = soil organic carbon-water partitioning coefficient (L/kg) (Supplement 4)

The SLERAP (Section 5.3.2.1 of EPA 1999) quoted for the use of equilibrium partitioning to estimate porewater concentrations states that the equilibrium-partitioning approach may be applied only when certain conditions are met:

- The fraction of organic carbon in soil (f_{oc}) is known.
- The COPCs must be nonpolar hydrophobic organic compounds.
- The COPCs must have mathematically derived water-to-tissue BCFs.

For this work plan, equilibrium partitioning can be applied to the subset of organic COPCs that have log K_{ow} and log K_{oc} values but do not have measured *BCF* values because each the above conditions are met, as described below:

- The approach is considered valid if f_{oc} is > 0.002 (EPA 1993b), whereas it has been accepted that the average of measured f_{oc} values is 0.0044 for the SLRA. This f_{oc} value is based on the sample data provided by Ecology (CCN 150854). This data indicates organic carbon content ranges from 0.21 to 0.77 percent (10 samples plus a duplicate sample, mean = 0.0044, standard deviation = 0.0022). The mean value will be used to model the soil invertebrate tissue concentration for the subset of organic COPCs mentioned in the text.
- The hydrophobic nature of a compound is indicated by its log K_{ow}. In the discussion of the technical basis for using equilibrium partitioning to derive sediment quality criteria (EPA 1993b), EPA shows sediment quality criteria for compounds with log K_{ow} above about 2.6, so any compound with a log K_{ow} greater than or equal to 2.6 should be considered sufficiently hydrophobic to meet the requirements of the method. The organic COPCs with BCF_S values calculated by SLERAP Eq. C-1-1 (EPA 1999) that also have log K_{ow} values greater than or equal to 2.6 and thus meet the requirement of being nonpolar, hydrophobic compounds with mathematically derived water *BCF*s are footnoted in Supplement 4.
- The organic COPCs for which K_{ow} is known have mathematically determined water-to-invertebrate *BCF*s.

The equilibrium-partitioning approach will be used for the organic COPCs that do not have measured BCF_S values but have log K_{ow} values ≥ 2.6. For the remaining organic COPCs that do not have measured BCF_S values but have log K_{ow} values < 2.6, the calculated BCF_W will be used to calculate tissue concentrations per SLERAP Table F-1-3. Per EPA (1999) it will be assumed that the pore water concentration is the same as the concentration in bulk soil. Therefore, the calculated BCF_S will be assumed to have units of kg soil/kg tissue.

EPCs in Mammal and Bird Tissues (Trophic Levels 2, 3, and 4)

For mammal and bird omnivores that are preyed upon by other predator receptors, the tissue EPC (C_{OM}) will be calculated as the sum of the contributions from the different types of material ingested. For transfer of COPCs and ROPCs to receptors by ingestion of plants, water, and soil, *BCF*s are used. For transfer of COPCs and ROPCs from prey to predators by ingestion of prey tissue, the food-chain multiplier (*FCM*) approach (EPA 1999) will be used to model transfer from one trophic level to another. Section 8.2.5.3 discusses *FCM*s. It is assumed that all mammals and birds ingest unfiltered water from the Columbia River maximum location. The equation describing the concentration of COPCs and ROPCs in receptor tissues is adapted from the SLERAP (EPA 1999, Eqs. 5-11, 5-12, and 5-13). The equation has been modified by simplification of the subscripts and removal of the summation (since exclusive diets are assumed). The equation takes the following form:

$$\begin{array}{c}\text{concentration}\\\text{in receptor}\end{array} = \begin{array}{c}\text{contaminants}\\\text{consumed}\\\text{from prey}\end{array} + \begin{array}{c}\text{contaminants}\\\text{consumed}\\\text{from plants}\end{array} + \begin{array}{c}\text{contaminants}\\\text{consumed}\\\text{from soil}\end{array} + \begin{array}{c}\text{contaminants}\\\text{consumed}\\\text{from water}\end{array}$$

where:

$$\begin{array}{c}\text{contaminants}\\\text{consumed}\end{array} = \begin{array}{c}\text{concentration}\\\text{in food or}\\\text{media}\end{array} \times \begin{array}{c}\text{bioconcentration}\\\text{factor}\end{array} \times \begin{array}{l}\text{fraction or proportion of food}\\\text{or media that is contaminated}\end{array}$$

such that the concentration in a omnivore is: (modified SLERAP Eq. 5-12)

$$C_{OM} = C_A \cdot \frac{FCM_{OM}}{FCM_A} \cdot F_A + C_{TP} \cdot BCF_P \cdot F_P + Cs_2 \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

and the concentration in a herbivore is: (modified SLERAP Eq. 5-11)

$$C_H = C_{TP} \cdot BCF_P \cdot F_P + Cs_2 \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

and the concentration in a carnivore is: (modified SLERAP Eq. 5-13)

$$C_C = C_A \cdot \frac{FCM_C}{FCM_A} \cdot F_A + Cs_2 \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

where:

$C_{OM/H/C}$	=	concentration of constituent in omnivorous, herbivorous, or carnivorous (respectively) receptor tissue (mg/kg FW tissue or pCi/g FW tissue)
C_A	=	concentration of constituent in ingested animal prey (mg/kg FW tissue or pCi/g FW tissue)
$FCM_{OM/C}$	=	food-chain multipliers for the omnivorous receptor (unitless)
FCM_A	=	food-chain multipliers for ingested prey type (unitless)
F_A	=	fraction of diet from animal tissue (unitless)
C_{TP}	=	concentration of constituent in ingested plant tissue (mg/kg plant or pCi/g plant)
BCF_P	=	plant-to-tissue uptake factor for omnivorous/herbivorous receptor (mg/kg FW tissue per mg/kg plant)
F_P	=	fraction of diet from plant tissue (unitless)
Cs_2	=	concentration of constituent in ingested soil (based upon an untilled 2-cm soil depth) (mg/kg or pCi/g),
BCF_S	=	soil-to-tissue uptake factor for omnivorous/herbivorous/carnivorous receptor (mg/kg FW tissue per mg/kg DW soil)

P_S	=	proportion of consumed soil or sediment that is contaminated (unitless)
C_{wctot}	=	concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)
BCF_W	=	water-to-tissue uptake factor for omnivorous/herbivorous/carnivorous receptor (mg/kg FW tissue per mg/L water)
P_W	=	proportion of consumed water that is contaminated (unitless)
CF	=	conversion factor for radionuclides, 0.001 pCi/kg to pCi/g

Per the SLERAP (EPA 1999), the plant-to-tissue, water-to-tissue, and soil-to-tissue *BCF*s are calculated from the receptor's ingestion rate and the published biotransfer factor (*Ba*). The *BCF*s are calculated using a modified version of SLERAP equations. The modification is necessary to derive *BCF*s from ingestion rates reported on a body-weight basis:

$$BCF_F = Ba \cdot IR_F \cdot BW \qquad \text{(modified SLERAP Eq. D-1-1)}$$

and:

$$BCF_M = Ba \cdot IR_M \cdot BW \qquad \text{(modified SLERAP Eq. D-1-2)}$$

where:

BCF_A	=	food-to-animal bioconcentration factor for receptor (mg COPC/kg FW tissue per mg COPC/kg FW food)
BCF_M	=	media-to-animal bioconcentration factor for receptor (mg COPC/kg FW tissue per mg COPC/kg DW media)
Ba	=	ingestion-to-tissue transfer factor (d/kg)
IR_F	=	daily food ingestion rate (kg/kg BW/d)
IR_M	=	daily media ingestion rate, such that: IR_w = rate of water consumption (L/kgBW/d) $IR_S = SFr \cdot IR_F$ = rate of soil consumption (kg/kg BW/d) SFr = soil ingested per unit food ingested (unitless)
BW	=	body weight of receptor (kg)

Soil consumption by receptors is incidental to the consumption of prey and plants. The amount of soil ingested per unit of food ingested (*SFr*) is used in conjunction with the food ingestion rate to determine the soil ingestion rate ($IR_S = IR_F \times SFr$).

According to EPA (1999), the fraction of the diet that is plants (F_P) is included in the calculation of BCF_P. Thus, an omnivore whose diet is 50 % plants would have a BCF_P half that of an herbivore with the same body weight and food ingestion rate. However, because F_P must be adjusted to either 1 or 0 for the exclusive diet, a fixed value of F_P cannot be included in the calculation of BCF_P. Therefore, F_P is not included as a part of BCF_P, but appears as a separate term in SLERAP Equation 5-12.

Values for IR_F, F_P, *BW*, *SFr*, and water ingestion (IR_w) for receptors exposed at terrestrial areas are given in the receptor profiles in Section 8.1.3.3. The values of *BCF* are discussed in Section 8.2.5.3. Values of

Ba, BCF_P (*BCF* for plants), BCF_S (*BCF* for soil), and BCF_W (*BCF* for water), for all COPCs and ROPCs for each receptor are reported in Supplement 4.

The EPCs for COPCs in plants, terrestrial invertebrates, and mammal and bird receptors that are eaten by other receptors will be used in the equations for modeling intake to terrestrial ecological receptors (i.e., the ingestion *DD*). Tissue EPCs for ROPCs are used for all receptors to calculate internal radiation exposure.

8.2.3.2 Modeling Intake to Terrestrial Ecological Receptors

The ingestion *DD* for terrestrial receptors will be calculated as the sum of the intakes of plant tissue, animal tissue, soil, and water. Thus:

$$DD = \sum IR_F \cdot C_i \cdot P_i \cdot F_i + \sum IR_M \cdot C_M \cdot P_M \qquad \text{(SLERAP Eq. 5-1)}$$

or:

$$DD = DD_A + DD_P + DD_S + DD_W$$

where:

DD	=	daily dose by ingestion (mg/kg BW/d)
IR_F	=	receptor plant or animal food item ingestion rate (kg/kg BW-day)
C_i	=	constituent concentration in i^{th} plant or animal food item (mg/kg)
P_i	=	proportion of i^{th} food item that is contaminated (unitless) - assumed to be equal to 1
F_i	=	fraction of diet consisting of plant or animal food item *i* (unitless)
IR_M	=	media *M* ingestion rate (kg/kg BW-day [soil or bed sediment] or L/kg BW-day [water])
C_M	=	constituent concentration in media *M* (mg/kg [soil or bed sediment] or mg/L [water])
P_M	=	proportion of ingested media *M* that is contaminated (unitless)
DD_A	=	daily dose by animal ingestion (mg/kg BW/d)
DD_P	=	daily dose by plant ingestion (mg/kg BW/d)
DD_S	=	daily dose by soil or sediment ingestion (mg/kg BW/d)
DD_W	=	daily dose by water ingestion (mg/kg BW/d)

As defined by Equation 5-1 of the SLERAP:

$$DD_A = C_A \cdot IR_F \cdot F_A$$
$$DD_P = C_{TP} \cdot IR_F \cdot F_P$$
$$DD_S = Cs_2 \cdot IR_F \cdot SFr$$
$$DD_W = C_{wctot} \cdot IR_W$$

where:

DD_A	=	daily dose by animal ingestion (mg/kg BW/d)
DD_P	=	daily dose by plant ingestion (mg/kg BW/d)
DD_S	=	daily dose by soil ingestion (mg/kg BW/d)
DD_w	=	daily dose by water ingestion (mg/kg BW/d)
C_A	=	concentration of constituent in ingested animal tissue (mg/kg)
C_P	=	concentration of constituent in ingested plant tissue (mg/kg)
IR_F	=	food (plant or prey, as applicable) ingestion rate of receptor (kg/kg BW/d)
F_A	=	fraction of diet from animals (unitless)
F_P	=	fraction of diet from plants (unitless)
Cs_2	=	concentration of constituent in ingested soil (mg/kg), based upon a 2-cm untilled soil depth
SFr	=	soil ingested per unit of food ingested (unitless)

The plant and animal food fractions sum to 1 ($F_P + F_A = 1$), and SFr is defined as the amount of soil ingested per unit of food ingested. Therefore, the total ingested fraction of food plus soil ($F_P + F_A + SFr$) is greater than 1 (e.g., for the western meadowlark $F_P = 0.3$, $F_A = 0.7$, and $SFr = 0.29$, so the total ingested fraction is 1.29).

Proportion of contaminated food and media (P_i and P_M), absorption efficiency (AE), the area use factor (AUF), and the temporal use factor (TUF) are assumed to be equal to 1, so they do not appear in the exposure equations.

8.2.3.3 Receptor-Specific Exposure Equations for Terrestrial Receptors

The complete equations for daily ingestion intake (DD) and animal tissue concentration (C_A) for each receptor are presented below.

Herbivores: Mule Deer and Mourning Dove (Trophic Level 2)

Mule deer and mourning doves are strict herbivores but ingest soil incidentally with their plant food and are assumed to ingest water from the Columbia River (Figure 8-8). Thus,

$$DD = DD_P + DD_S + DD_W\text{, or} \qquad \text{(Equation 8-1)}$$

$$DD_{Deer} = C_{TP} \cdot IR_F \cdot F_P + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

$$DD_{Dove} = C_{TP} \cdot IR_F \cdot F_P + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

where C_{TP}, IR_F, Cs_2, SFr, C_{wctot}, and IR_w are as given above. The mule deer and mourning dove food ingestion rates (IR_F), dietary fractions (F_P and SFr), and water ingestion rates (IR_w) are given in the receptor profiles in Section 8.1.3.3.

Deer and dove tissue concentrations are calculated by an equation with the applicable exposure routes in SLERAP Equation 5-11:

$$C_{Deer} = C_{TP} \cdot BCF_P \cdot F_P + Cs_2 \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

$$C_{Dove} = C_{TP} \cdot BCF_P \cdot F_P + Cs_2 \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

where:

$C_{Deer/Dove}$	=	concentration of COPC or ROPC in receptor tissue (mg/kg or pCi/g)
C_{TP}	=	concentration of COPC or ROPC in ingested plant tissue (mg/kg or pCi/g)
F_P	=	fraction of diet from plants (unitless)
BCF_P	=	plant-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg plant)
Cs_2	=	concentration of constituent in ingested soil (mg/kg or pCi/g), based upon a 2-cm untilled soil depth
BCF_S	=	soil-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg DW soil)
C_{wctot}	=	total concentration of ROPC in water (mg/kg or pCi/L)
BCF_W	=	water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)
CF	=	conversion factor for radionuclides, 0.001 pCi/kg to pCi/g

The soil-to-tissue concentration factors (BCF_S), plant-to-tissue concentration factors (BCF_P), and water-to-tissue uptake factors (BCF_W), respectively, for mule deer and mourning doves are reported in Supplement 4.

Omnivores: Great Basin Pocket Mouse and Western Meadowlark (Trophic Level 3)

Great Basin pocket mouse and western meadowlark are omnivores that ingest plants and invertebrates, and ingest soil incidentally with their food. The western meadowlark is assumed to ingest water from the Columbia River whereas the Great Basin pocket mouse is assumed to obtain water through its food (Figure 8-8). The receptor dose includes the contribution of food, soil and water (for the meadowlark):

$$DD = DD_A + DD_P + DD_S + DD_W \text{, or} \qquad \text{(Equation 8-2)}$$

$$DD = C_A \cdot IR_F \cdot F_A + C_{TP} \cdot IR_F \cdot F_P + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

where C_A, C_{TP}, IR_F, Cs_2, SFr, C_{wctot}, and IR_w are as given above (Equation 8-2 first appears in Section 8.2.3.2). The pocket mouse and Western meadowlark food ingestion rates (IR_F), water ingestion rates (IR_w), and dietary fractions (F_A, F_P) and soil fraction (SFr), are given in the receptor profiles in Section 8.1.3.3. The SLERA will evaluate the exposure of mouse and meadowlark assuming ingestion of only the food type with the highest tissue concentration. Thus, the concentration of each COPC and each ROPC will be calculated for plants and terrestrial invertebrates, and the higher concentration will be used in the exposure calculation. The terrestrial food web (Figure 8-8) shows that the sole animal prey type for the Great Basin pocket mouse and western meadowlark are terrestrial invertebrates. Whether plants or terrestrial invertebrates have the higher tissue concentration is a function of the soil-to-tissue uptake factor for the two food types. For the exclusive diets, if the herbivore diet for a given constituent is the main source of tissue contamination, F_P is one and F_A is zero ($C_P > C_A$). If the carnivore diet for a given constituent is the main source of tissue contamination, F_P is zero and F_A is one ($C_A > C_P$) (Figure 8-10). Selection of the exclusive diet is made on a constituent-by-constituent basis. The use of the exclusive diet in the evaluation of the worst-case scenario is discussed in Section 8.2.1. The corresponding dose equations are therefore:

for plant consumption (herbivore diet, $C_P > C_A$):

$$DD_{Mouse} = C_{TP} \cdot IR_F \cdot F_P + Cs_2 \cdot IR_F \cdot SFr \qquad \text{(Equation 8-3)}$$

$$DD_{Lark} = C_{TP} \cdot IR_F \cdot F_P + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

and for consumption of invertebrates (carnivore diet, $C_A > C_P$):

$$DD_{Mouse} = C_{INV} \cdot IR_F \cdot F_A + Cs_2 \cdot IR_F \cdot SFr \qquad \text{(Equation 8-4)}$$

$$DD_{Lark} = C_{INV} \cdot IR_F \cdot F_A + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

Great Basin pocket mouse and western meadowlark tissue concentrations are calculated by equations adapted from the SLERAP Equations 5-12 and 5-13:

for plant consumption (herbivore diet, $C_P > C_A$):

$$C_{Mouse} = C_{TP} \cdot BCF_P \cdot F_P + Cs_2 \cdot BCF_S$$

$$C_{Lark} = C_{TP} \cdot BCF_P \cdot F_P + Cs_2 \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

and for consumption of invertebrates (carnivore diet, $C_A > C_P$):

$$C_{Mouse} = C_{INV} \cdot \frac{FCM_3}{FCM_2} \cdot F_A + Cs_2 \cdot BCF_S$$

$$C_{Lark} = C_{INV} \cdot \frac{FCM_3}{FCM_2} \cdot F_A + Cs_2 \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

where:

$C_{Mouse/Lark}$	=	concentration of constituent in receptor tissue (mg/kg or pCi/g)
C_{TP}	=	concentration of constituent in ingested plant tissue (mg/kg or pCi/g)
BCF_P	=	plant-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg plant)
F_P	=	fraction of diet from plants (unitless)
C_{INV}	=	concentration of constituent in ingested invertebrate (mg/kg or pCi/g)
FCM_3	=	food-chain multipliers for the receptor (unitless)
FCM_2	=	food-chain multipliers for ingested prey type (unitless)
F_A	=	fraction of diet from animals (unitless)

Cs_2 = concentration of COPC or ROPC in ingested soil (mg/kg or pCi/g), based upon a 2-cm untilled soil depth

BCF_S = soil-to-tissue bioconcentration factor for receptor (mg/kg FW tissue per mg/kg DW soil)

C_{wctot} = total concentration of COPC (mg/L) or ROPC (pCi/L) in water

BCF_W = water-to-tissue bioconcentration factor (kg FW tissue per mg/L water)

CF = conversion factor, 0.001 pCi/kg to pCi/g

The FCMs for the pocket mouse and western meadowlark (FCM_3) and their prey (FCM_2) are reported in Supplement 4. The soil-to-tissue bioconcentration factors (BCF_S), plant-to-tissue bioconcentration factors (BCF_P), and water-to-tissue bioconcentration factor (BCF_W) are reported in Supplement 4.

Carnivores: Coyote and Burrowing Owl (Trophic Level 4)

Coyotes and burrowing owls are carnivores that ingest primarily small animals, but also a small fraction of soil incidentally with their food and are assumed to ingest water from the Columbia River (Figure 8-8). The SLERA will evaluate the exposure of coyotes and burrowing owls as carnivores, assuming ingestion of only the animal prey type with the highest tissue concentration. Figure 8-11 shows how the exposure of carnivores is calculated using existing diet for the case where soil invertebrates have a higher estimated tissue concentration than plants. Whether meadowlarks or pocket mice have the highest tissue concentration is a function of the soil-to-tissue and other uptake factors for those prey types. Thus:

$$DD = DD_A + DD_S + DD_W \text{, or} \qquad \text{(Equation 8-1)}$$

$$DD = C_A \cdot IR_F \cdot F_A + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

where C_A, IR_F, Cs_2, SFr, C_{wctot}, and IR_w are as given above. DD_A is calculated for the prey type with the highest expected body burden for a given constituent. The value of F_A (F_{Mouse} and F_{Lark}) is the value shown in the appropriate table entry in Section 8.1.3.3 for the exclusive diet, or zero for the non-exclusive diet. Because of the exclusive diet assumption, the prey that has the greatest contribution to the accumulation of a given contaminant in the receptor tissue is the sole source of that contaminant. Accordingly, the prey that has the least contribution of a given contaminant is not considered (F_A is set to zero). For example, if the coyote's uptake for constituent "X" is greatest from the mouse, and for constituent "Y" is greatest from the lark, it is assumed that the coyote will be exposed to "X" solely from preying upon mice, and the contribution of constituent "Y" to the coyote's dose will come from exclusive consumption of lark. The corresponding dose equations are therefore:

For a diet exclusive to Great Basin pocket mouse consumption ($C_{Mouse} > C_{Lark}$):

$$DD_{Coyote} = C_{Mouse} \cdot IR_F \cdot F_{Mouse} + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W \qquad \text{(Equation 8-5)}$$

$$DD_{Owl} = C_{Mouse} \cdot IR_F \cdot F_{Mouse} + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

For a diet exclusive to western meadowlark consumption ($C_{Lark} > C_{Mouse}$):

$$DD_{Coyote} = C_{Lark} \cdot IR_F \cdot F_{Lark} + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W \qquad \text{(Equation 8-6)}$$

$$DD_{Owl} = C_{Lark} \cdot IR_F \cdot F_{Lark} + Cs_2 \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

Coyote and burrowing owl food ingestion rate (IR_F), dietary fraction (F_A and SFr), and water ingestion rate (IR_w) are given in the receptor profiles in Section 8.1.3.3. The terrestrial food web (Figure 8-8) shows that the sole prey types of the coyote and burrowing owl to be evaluated in the SLERA are the Great Basin pocket mouse and the western meadowlark.

Coyote and burrowing owl tissue concentrations of will be calculated by an equation adapted from the SLERAP Equation 5-13:

for a diet exclusive to Great Basin pocket mouse consumption ($C_{Mouse} > C_{Lark}$):

$$C_{Coyote} = C_{Mouse} \cdot \frac{FCM_4}{FCM_3} \cdot F_{Mouse} + Cs_2 \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

$$C_{Owl} = C_{Mouse} \cdot \frac{FCM_4}{FCM_3} \cdot F_{Mouse} + Cs_2 \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

for a diet exclusive to western meadowlark consumption ($C_{Lark} > C_{Mouse}$):

$$C_{Coyote} = C_{Lark} \cdot \frac{FCM_4}{FCM_3} \cdot F_{Lark} + Cs_2 \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

$$C_{Owl} = C_{Lark} \cdot \frac{FCM_4}{FCM_3} \cdot F_{Lark} + Cs_2 \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

where:

$C_{Coyote/Owl}$	=	concentration of in receptor tissue (mg/kg or pCi/g)
$C_{Mouse/Lark}$	=	concentration of in prey tissue (mg/kg or pCi/g)
FCM_4	=	food-chain multipliers for the receptor (unitless)
FCM_3	=	food-chain multipliers for ingested prey type (unitless)
F_{Mouse}	=	fraction of diet from Great Basin pocket mouse tissue (unitless)
F_{Lark}	=	fraction of diet from western meadowlark tissue (unitless)
Cs_2	=	concentration of constituent in ingested soil (mg/kg or pCi/g), based upon a 2-cm untilled soil depth
BCF_S	=	soil-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg DW soil)
C_{wctot}	=	total concentration of constituent in water (mg/L or pCi/L)
BCF_W	=	water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)
CF	=	conversion factor, 0.001 pCi/kg to pCi/g

For the exclusive diet, $F_A = 1$ for the prey type contributing the most to receptor tissue uptake, and zero for the receptor contributing the least. The *FCM*s for the coyote and burrowing owl ($FCM_{Coyote/Owl}$) and their prey ($FCM_{Mouse/Lark}$) are reported in Supplement 4. Soil-to-tissue uptakes factors (BCF_S) and water-to-tissue uptake factors (BCF_W) for the coyote and burrowing owls are reported in Supplement 4.

Carnivore: Red-tailed hawk (Trophic Level 4)

Red-tailed hawks are carnivores that ingest small animals but do not ingest soil incidentally with their food. They are assumed to ingest water from the Columbia River (Figure 8-8). The SLERA will evaluate the exposure of red-tailed hawks assuming ingestion of only the prey type with the highest tissue concentration (Figure 8-11). Thus, the concentration of each COPC and ROPC in mice and meadowlarks will be calculated, and the higher concentration will be used in the exposure evaluation. Whether meadowlarks or Great Basin pocket mice have the higher tissue concentration is a function of the soil-to-tissue and other uptake factors for those prey types. Thus,

$$DD = DD_A + DD_W \text{, or} \qquad \text{(Equation 8-7)}$$

$$DD = C_A \cdot IR_F \cdot F_A + C_{wctot} \cdot IR_W$$

where DD_A is calculated for prey type with the highest expected body burden for a given constituent with $F_A = 1$. DD_W is as given above. The corresponding dose equations are therefore:

for a diet exclusive to Great Basin pocket mouse consumption ($C_{Mouse} > C_{Lark}$):

$$DD_{Hawk} = C_{Mouse} \cdot IR_F \cdot F_{Mouse} + C_{wctot} \cdot IR_W \qquad \text{(Equation 8-8)}$$

for a diet exclusive to western meadowlark consumption ($C_{Lark} > C_{Mouse}$):

$$DD_{Hawk} = C_{Lark} \cdot IR_F \cdot F_{Lark} + C_{wctot} \cdot IR_W \qquad \text{(Equation 8-9)}$$

Red-tailed hawk food ingestion rate (IR_F) and water ingestion rate (IR_w) are given in the receptor profiles in Section 8.1.3.3. The terrestrial food web (Figure 8-8) shows the prey types for the hawk. The hawk prey types to be evaluated in the SLERA are the Great Basin pocket mouse and the western meadowlark.

Red-tailed hawk tissue concentrations of ROPCs are calculated by an equation adapted from the SLERAP Equation 5-13:

for a diet exclusive to Great Basin pocket mouse consumption ($C_{Mouse} > C_{Lark}$):

$$C_{Hawk} = C_{Mouse} \cdot \frac{FCM_4}{FCM_3} \cdot F_{Mouse} + C_{wctot} \cdot BCF_W \cdot CF$$

for a diet exclusive to western meadowlark consumption ($C_{Lark} > C_{Mouse}$):

$$C_{Hawk} = C_{Lark} \cdot \frac{FCM_4}{FCM_3} \cdot F_{Lark} + C_{wctot} \cdot BCF_W \cdot CF$$

where:

C_{Hawk} = concentration of in receptor tissue (mg/kg or pCi/g)
$C_{Mouse/Lark}$ = concentration of in prey tissue (mg/kg or pCi/g)
FCM_4 = food-chain multipliers for the receptor (unitless)
FCM_3 = food-chain multipliers for ingested prey type (unitless)
F_{Mouse} = fraction of diet from Great Basin pocket mouse tissue (unitless)
F_{Lark} = fraction of diet from western meadowlark tissue (unitless)
C_{wctot} = total concentration of constituent in water (mg/L or pCi/L)
BCF_W = water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)
CF = conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

For the exclusive diet, F_A = 1 for the prey type contributing the most to receptor tissue uptake, and zero for the receptor contributing the least. The FCMs for hawks (FCM_4) and their prey (FCM_3) are reported in Supplement 4 along with water-to-tissue uptake factors (BCF_W).

8.2.3.4 External and Internal Radiation Dose

The total radiological dose to all receptors is calculated as the sum of the external and internal radiation doses for all ROPCs, using methods presented by Sample et al. (1997). External doses to all receptors result from exposure to ROPCs in soil and air. The internal dose to plants and terrestrial invertebrates results from the uptake of radionuclides into their tissues from soil. The internal dose to wildlife receptors results from the uptake of radionuclides into their tissues from ingested food, soil, and water.

The total radiological dose is calculated as:

$$DD = DD_E + DD_I \qquad \text{(Equation 8-10)}$$

where:

DD = total radiation dose to the receptor (rad/day)
DD_E = total external radiation dose (rad/day)
DD_I = internal radiation dose (rad/day)

All radiation damage results from interaction of ionizing radiation with molecules in the tissues. As each ROPC decays, it emits radiation that is characteristic for that ROPC. The energy absorbed by tissues depends on the type and energy of radiation and the amount of tissue that absorbs the energy. Thus, alpha particles and most beta radiation do not penetrate the skin and do not cause damage by external radiation. Also, the fraction of gamma radiation from any ROPC that is absorbed by tissue is higher for large animals than for small animals. Internal alpha radiation does more damage to tissues per unit of energy. To adjust for the additional damage, a quality factor (QF) is used: the alpha energy is multiplied by QF in the exposure equations. In a paper by Kocher and Trabalka (2000) it is indicated a quality factor of 5 was suggested by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1996), but states that the rationale for the value was not substantiated. Kocher and Trabalka (2000) state that the quality factor probably lies between 5 and 10. Based on this paper, the RAWP will use a quality factor of 10 (upper end of probable range) for alpha energy. The quality factors for beta and gamma radiation are 1.

External Dose

External radiation doses from air and soil will be calculated by methods presented by Eckerman and Ryman (1993, same as EPA 1993c), Blaylock, Frank, and O'Neal (1993), and Sample et al. (1997) because the SLERAP (EPA 1999) does not provide methods to evaluate radiation doses. Sample et al. (1997) is a published report from Oak Ridge National Laboratory and not agency guidance. The method of Sample et al. (1997) to calculate belowground external radiation to terrestrial invertebrates will be adapted for use to calculate external doses to belowground portions of plants. Exposures of terrestrial receptors to external radiation will be calculated as follows:

- **Terrestrial plants** – aboveground parts by immersion in air and contact with the soil surface and belowground parts by immersion in soil
- **Terrestrial invertebrates** – immersion in air and contact with the soil surface while aboveground and immersion in soil while belowground
- **Mule deer** – immersion in air and radiation from the soil surface
- **Mourning dove** – immersion in air and radiation from the soil surface
- **Great Basin pocket mouse** – immersion in air and radiation from the soil surface while aboveground and immersion in soil while belowground
- **Western meadowlark** – immersion in air and radiation from the soil surface
- **Coyote** – immersion in air and radiation from the soil surface while aboveground and immersion in soil while belowground
- **Burrowing owl** – immersion in air and radiation from the soil surface while aboveground and immersion in soil while belowground
- **Red-tailed hawk** – immersion in air and radiation from the soil surface

External irradiation by immersion in air containing ROPCs and by standing, sitting, or lying on the soil surface (aboveground radiation) will be modeled by using external dose conversion factors (*DCF*s) (Eckerman and Ryman 1993) and the activity of ROPCs in the medium.

Aboveground external radiation from soil will be adjusted for the fraction of time that the receptor is assumed to spend on the soil surface, chosen by scientific judgment based on narrative information in published and internet wildlife articles.

There is also a roughness factor of 0.7 to correct for absorption of radiation by uneven soil contours and an elevation correction factor (*ECF*) to adjust *DCF*s to account for most ecological receptors having most of their bodies closer to the ground than the humans for which the *DCF*s were derived. The *ECF* is 2 for all receptors except mule deer, which are large enough to receive radiation at approximately the same height as humans (Sample et al. 1997). The elevation correction factor of 2 for all receptors except the mule deer assumes that these receptors receive twice the exposure from the same concentrations of ROPCs in soil. External radiation *DCF*s are presented in Supplement 4.

Belowground external radiation from soil will be modeled by using the decay energies and tissue absorption fractions presented in Supplement 4. Equations to calculate belowground external exposure are presented by Sample et al. (1997). Belowground exposure is adjusted for the fraction of time that the receptor is assumed to be exposed underground, chosen by scientific judgment based on narrative information in published wildlife articles.

The fraction of time a receptor spends above ground (on the ground surface) and belowground are assumed to be:

	Fraction of time above ground	Fraction of time below ground
Plants	0.5	0.5
Terrestrial invertebrates	0.5	0.5
Mule deer	1	0
Mourning dove	1	0
Great Basin pocket mouse	0.3	0.7
Western meadowlark	1	0
Coyote	0.7	0.3
Burrowing owl	0.5	0.5
Red-tailed hawk	0.05[a]	0

[a] It is assumed the red-tailed hawk spends 95 % of the time in flight or perched such that there is negligible exposure due to radionuclides in the soil.

As presented implicitly by Eckerman and Ryman (1993) and in Blaylock, Frank, and O'Neal (1993), the external dose (rad/day) to all receptors for a given radionuclide in the will be calculated as:

$$DD_E = \sum (\text{ROPC Concentration} \cdot \text{Dose Conversion Factor})$$

where DD_E is the external radiation dose (rad/day). External radiation exposure occurs from three media types; soil, air, and water. Soil and water exposure can include receptor exposure to the surface of the soil or water, and exposure from immersion in the soil and water. Air exposure is solely due to immersion. For terrestrial receptors, the external dose from water exposure is considered negligible because the receptor contact with the Columbia River is limited.

$$DD_E = DD_{E_{soil}} + DD_{E_{air}}$$

where:

DD_E = total external radiation dose (rad/day)

$DD_{E_{soil}}$ = external radiation dose from sediment (rad/day)

$DD_{E_{air}}$ = external radiation dose from air (rad/day)

The external daily dose due to soil contact is:

$$DD_{E_{soil}} = DD_{abovegrd} + DD_{belowgrd}$$

where:

$DD_{E_{soil}}$ = external radiation dose from soil (rad/day)
$DD_{abovegrd}$ = external dose from exposure to aboveground soil (rad/day)
$DD_{belowgrd}$ = external dose from exposure to belowground soil (rad/day)

The total external dose from all ROPCs in soil is the sum of the external doses from each ROPC. Following the method of Sample et al. (1997), the external dose from exposure to soil ($DD_{abovegrd}$ and $DD_{belowgrd}$) will be calculated as:

$$DD_{abovegrd} = F_{above} \cdot F_{ruf} \cdot Cs_2 \cdot DCF_{grd} \cdot CFb \cdot ECF \qquad \text{(Sample et al. (1997), Eq. 9)}$$

$$DD_{belowgrd} = 1.05 \cdot F_{below} \cdot Cs_2 \cdot E_\gamma \cdot AbF_\gamma \cdot CFa \qquad \text{(modified Sample et al. (1997), Eq. 10)}$$

Factoring Cs_2, substituting variables to represent the dose factor yields the following equations:

$$DD_{E_{soil}} = \left(F_{above} \cdot F_{ruf} \cdot DCF_{grd} \cdot CFb \cdot ECF + 1.05 \cdot F_{below} \cdot Cs_2 \cdot E_\gamma \cdot AbF_\gamma \cdot CFa\right) \cdot Cs_2 \text{, or}$$
$$DD_{E_{soil}} = \left(DCF_{abovegrd} + DCF_{belowgrd}\right) \cdot Cs_2 \text{, or}$$
$$DD_{E_{soil}} = DCF_{soil} \cdot Cs_2$$

Thus, the external dose to a terrestrial receptor due to soil exposure to a ROPC will be calculated according to:

$$DD_{E_{soil}} = DCF_{soil} \cdot Cs_2 \text{, and}$$
$$DF_{soil} = F_{above} \cdot F_{ruf} \cdot DCF_{grd} \cdot CFb \cdot ECF + 1.05 \cdot F_{below} \cdot F_{ruf} \cdot E_\gamma \cdot AbF_\gamma \cdot CFa$$

where:

$DD_{E_{soil}}$ = external radiation dose from soil (rad/day)
DCF_{soil} = factor for converting activity of radionuclide in soil to external dose from exposure to aboveground and belowground soil in units of rad/day per pCi/g ($DCF_{soil} = DCF_{abovegrd} + DCF_{belowgrd}$)
$DCF_{abovegrd}$ = factor for converting activity of radionuclide in soil to external dose from exposure to aboveground soil in units of rad/day per pCi/g ($DCF_{abovegrd} = F_{above} \cdot F_{ruf} \cdot DCF_{grd} \cdot CFb \cdot ECF$)
$DCF_{belowgrd}$ = factor for converting activity of radionuclide in soil to external dose from exposure to belowground soil in units of rad/day per pCi/g ($DCF_{belowgrd} = 1.05 \cdot F_{below} \cdot F_{ruf} \cdot E_\gamma \cdot AbF_\gamma \cdot CFa$)

DCF_{grd}	= dose conversion factor for external radiation by the ROPC from soil contaminated to a depth of 5 cm (Sv/s per Bq/m^3), using effective doses (dose averaged over all body organs) (Eckerman and Ryman 1993, Table III.4)
F_{above}	= fraction of time spent above ground (unitless)
F_{below}	= fraction of time spent below ground surface (unitless)
F_{ruf}	= dose rate reduction factor accounting for ground roughness (unitless); a value of 0.7 is considered a representative average reduction factor (Eckerman and Ryman 1993)
CFb	= 5.115×10^{11}, factor[1] to convert Sv/s per Bq/m^3 to rad/day per pCi/g
ECF	= elevation correction factor to adjust dose coefficient for effective height of receptor above ground (unitless, Sample et al. 1997)
1.05	= conversion factor to account for immersion in soil rather than water (unitless)
E_γ	= photon energy emitted during transition from a higher to a lower energy state × proportion of disintegrations producing γ radiation (MeV/disintegration)
AbF_γ	= absorbed fraction of energy from gamma energy E_γ (unitless)
CFa	= unit conversion factor[2], 5.122×10^{-5} rad/day per pCi/g per MeV/disintegration
Cs_2	= activity of the radionuclide in untilled soil of 2 cm depth (pCi/g)

Note that the modification of Equation 10 of Sample et al. (1997) includes terms for energy emitted and the fraction absorbed. Sample et al. (1997) present absorbed fractions for select radionuclides but neglect to explicitly show them in Equation 10; thus, the equation above has been modified to clearly show application of the absorbed fraction in the dose factor computation. DCF_{grd} for soil, E_γ, and AbF_γ are reported in Supplement 4. To calculate external exposure to radionuclides in soil, DCF_{soil} values will be multiplied by the modeled activities of the corresponding radionuclides in surface soil at each exposure location.

The external dose (rad/day) to all receptors from air will be calculated as:

$$DD_{E_{air}} = DCF_{air} \cdot C_a \qquad \text{(Eckerman and Ryman 1993)}$$

where:

$DD_{E_{air}}$	=	external radiation dose from air (rad/day)
DCF_{air}	=	factor for converting activity of the ROPC in air to external dose from air (rad/day per pCi/m^3
C_a	=	activity of the ROPC in air, calculated as described in Section 6.1 (pCi/m^3)

The external dose conversion factor for air (DCF_{air}) will be calculated as follows:

$$DCF_{air} = 3.197 \times 10^5 \cdot DCF \qquad \text{(Eckerman and Ryman 1993)}$$

[1] Per Eckerman and Ryman, a soil density conversion factor of 1.6×10^3 kg/m^3 is applied such that the appropriate conversion factor is: [(Sv/s)/(Bq/m^3)] × (100 rad/Sv) × (86400 s/day) × (0.037 Bq/pCi) × (10^3 g/kg) × (1.6×10^3 kg/m^3) = 5.115×10^{11} (rad·g)/(pCi·day)

[2] Conversion factor: (pCi/g) × (MeV/disintegration) × (0.037 disintegration/s)/pCi × (1.602×10^{-8} rad/(MeV/g)) × (86400 s/day) = 5.122×10^{-5} rad/day

where:

3.197×10^5 = conversion factor[3] to convert Sv/s per Bq/m^3 to rad/day per pCi/m^3 (Eckerman and Ryman 1993)

DCF = dose conversion factor for external radiation from immersion in air (Sv/s per Bq/m^3, Eckerman and Ryman 1993)

For all ROPCs, values of DCF_{air} for air are reported in Supplement 4. To calculate external exposure to radionuclides in air, DCF_{air} values will be multiplied by the modeled activities of the corresponding radionuclides in air at each exposure location.

Internal Dose

The internal exposure to radionuclides will be calculated from the activity in the receptor's tissues rather than from the daily ingestion. The internal activities of ROPCs are calculated by using *BCF*s and ROPC activities in soil and food as described in Section 8.2.3.3. Internal radiation doses are calculated by multiplying the activity in tissues by the sum of alpha, beta, and gamma decay energies, where alpha and beta energies are assumed to be completely absorbed. Because gamma rays, like X-rays, may pass through the tissues without depositing their energy, gamma energies are adjusted to account for greater absorption by larger organisms at a given energy level and for greater absorption by all receptors at lower energy levels. Radiation by daughter radionuclides was also included in internal dose calculations. Daughter radionuclides are produced by decay of parent radionuclides and short-lived radionuclides could be expected to contribute to the receptor's internal dose. Exposures are calculated by assuming that the decay products of all short-lived ROPCs are in secular equilibrium and equal to the activity of the parent multiplied by the fraction of the decays in the immediately preceding generation that yield the daughter radionuclide. Decay energies (Eckerman and Ryman 1993) and absorption fractions for gamma radiation (Blaylock, Frank, and O'Neal 1993; Sample et al. 1997) of daughter radionuclides are reported in Supplement 4.

Adapting Equation 11 of Sample et al. (1997), the internal dose (rad/day) to plants, terrestrial invertebrates, and wildlife receptors will be calculated as follows:

$$DD_I = \sum QF \cdot C_{TP \text{ or } INV \text{ or } A} \cdot E \cdot CF \cdot AbF \qquad \text{(modified Sample et al. (1997), Eq. 11)}$$

where:

DD_I = internal radiation dose (rad/day)

QF = quality factor for relative biological effect of radiation (unitless) (Kocher and Trabalka 2000)

QF_α = 10 for alpha radiation

QF_β = 1 for beta radiation

QF_γ = 1 for gamma radiation

[3] Conversion factor: $[(\text{Sv/s})/(\text{Bq/m}^3)] \times (100 \text{ rad/Sv}) \times (86400 \text{ s/day}) \times (0.037 \text{ Bq/pCi}) = 3.197{\times}10^3 \ (\text{rad}\cdot\text{m}^3)/(\text{pCi}\cdot\text{day})$

$C_{TP \text{ or } INV \text{ or } A}$	=	activity of radionuclide in receptor tissue (terrestrial plant, invertebrate, or animal - see Section 8.2.3.3) (pCi/g)
CF	=	unit conversion factor, 5.12×10^{-5} rad/day per pCi/g per MeV/disintegration
E	=	average energy emitted as alpha, beta, or gamma radiation by radionuclide i × proportion of disintegrations producing alpha, beta, or gamma radiation (MeV per disintegration)
AbF	=	absorbed fraction of energy from alpha, beta, or gamma energy (unitless)

The equation above can be expanded to show the variables specific to the types of radiation emitted from the ROPC.

$$DD_I = \left(QF_\alpha \cdot E_\alpha \cdot AbF_\alpha + QF_\beta \cdot E_\beta \cdot AbF_\beta + QF_\gamma \cdot E_\gamma \cdot AbF_\gamma\right) \cdot CF \cdot C_{TP \text{ or } INV \text{ or } A}$$

substituting variables to represent the dose factor yields:

$$DD_I = DCF_I \cdot C_{TP \text{ or } INV \text{ or } A}\text{, and}$$

$$DCF_I = \left(QF_\alpha \cdot E_\alpha \cdot AbF_\alpha + QF_\beta \cdot E_\beta \cdot AbF_\beta + QF_\gamma \cdot E_\gamma \cdot AbF_\gamma\right) \cdot CF$$

where QF_α, QF_β, and QF_γ are the quality factors of alpha, beta, and gamma radiation (respectively), E_α, E_β, and E_γ are the product of the average energy emitted and proportion of disintegrations producing alpha, beta, and gamma radiation (respectively), and AbF_α, AbF_β, and AbF_γ are absorbed fraction of energy from alpha, beta, and gamma energy (respectively). Other terms are as defined above. Internal exposure dose factors for aquatic receptors include the contribution of daughter products:

$$DCF_{I+D} = DCF_{I_{parent}} + \sum_{i=1}^{n} DCF_{I_D}$$

where

DCF_{I+D}	=	factor for converting activity of radionuclide (and its daughter products) to internal dose from ingestion of contaminated food in units of rad/day per pCi/g
$DCF_{I_{parent}}$	=	factor for converting activity of the parent radionuclide to internal dose from exposure in units of rad/day per pCi/g
$\sum_{i=1}^{n} DCF_{I_D}$	=	sum of the daughter product dose factors for each applicable daughter product (1 through n) for converting activity of the daughter product to internal dose in units of rad/day per pCi/g

Values of E and AbF for each radiation (alpha, beta and gamma) are reported in Supplement 4 for all ROPCs and their daughters, respectively. To calculate internal exposure to radionuclides in soil, DCF_I values will be multiplied by the modeled activities of the corresponding radionuclides in receptor tissues at each exposure location.

8.2.4 Quantification of Exposure at the Columbia River Maximum (Aquatic Receptors)

Calculating ecological screening quotients (*ESQ*s) for receptors exposed to contaminated air, water, and sediment in the Columbia River area by direct contact with air, sediment, and water and by ingestion of water, sediment, and biota requires the EPCs of COPCs and ROPCs in air, water, sediment, and aquatic biota. The EPCs of COPCs in biota (Section 8.2.4.1) are required to calculate the *DD* by ingestion (Sections 8.2.4.2 and 8.2.4.3) and internal radiation dose for predator receptors. The total radiation dose for all receptors exposed to ROPCs is the sum of the external and internal radiation doses for all ROPCs (Section 8.2.4.4).

The exposure of terrestrial predators to terrestrial prey at the onsite ground maximum is higher than exposure at the Columbia River maximum because concentrations in the soil at the onsite ground maximum are by definition higher than concentrations at the Columbia River maximum, which is farther from the emission source than the onsite ground maximum. Ingestion of terrestrial prey by eagles and mink at the Columbia River maximum (which would be modeled by the same exposure pathways as ingestion by coyotes and hawks) will be less than the maximum onsite risk already calculated for ingestion of terrestrial prey by coyotes and hawks at the onsite ground maximum because the concentrations in prey will be much lower in proportion to the soil concentrations. Although body weight, metabolism, and ingestion rate differ among organisms, these differences represent a much smaller contribution to exposure and risk predictions than does the much larger difference in soil concentrations between the On-Site Ground Maximum and the Columbia River Maximum.

The intent of evaluating exposure at the Columbia River maximum is to determine the risks from deposition of COPCs and ROPCs into surface water. To ensure that exposure by deposition of COPCs and ROPCs into surface water is maximized, exposure to aquatic and benthic prey is evaluated at the Columbia River maximum and propagated through the food chain to higher trophic level receptors.

8.2.4.1 EPCs in Aquatic Biota

Calculating EPCs for tissues of aquatic plants and animals exposed by direct contact with air, water, and sediment requires the EPCs of COPCs and the ROPCs in air (C_a), dissolved in water (C_{dw}), in water column as a total (C_{wctot}), in sediment (C_{sed}), as well as the receptor bioaccumulation and uptake factors for the COPCs and ROPCs (Section 8.2.5.4).

EPCs in Aquatic Plants (Trophic Level 1)

For floating and rooted aquatic plants exposed to COPCs and ROPCs in surface water and sediment, respectively, and fed upon by Canada geese, the tissue EPC will be calculated in accordance with the SLERAP (EPA 1999), using concentration of COPCs and ROPCs in river sediment (C_{sed}):

$$C_{AP} = C_M \cdot BCF_M \cdot CF \qquad \text{(SLERAP Eq. 5-3)}$$

where:

C_{AP} = concentration or activity of COPCs or ROPCs in aquatic plant tissue (mg/kg or pCi/g)
C_M = concentration or activity of COPCs or ROPCs in the media of interest (C_{dw}, dissolved in surface water in mg/L or pCi/L, or C_{sed}, sediment in mg/kg, or pCi/g)
BCF_M = media-to-plant bioconcentration factor (water-to-tissue uptake factor for floating plants in L/kg, or unitless sediment-to-tissue uptake factor for rooted aquatic plants)

CF = conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

In order to be conservative, it is assumed that the diet of the Canada goose is exposed to COPCs and ROPCs in both surface water and sediment (Figure 8-9). The values of BCF_M for the SLERA are discussed in Section 8.2.5.4. For all COPCs and ROPCs, values for BCF_M are reported in Supplement 4.

EPCs in Benthic Invertebrates (Trophic Level 2)

For benthic invertebrates exposed to organic COPCs and ROPCs in sediment and fed upon by spotted sandpipers and great blue herons, the tissue EPC will be calculated by using either a measured sediment-to-invertebrate bioconcentration factor or a calculated sediment porewater concentration and an empirically determined water-to-invertebrate bioconcentration factor. The EPCs for constituents with measured bioconcentration factors are calculated in accordance with EPA (1999) draft guidance:

$$C_{INV} = C_{sed} . BCF_S \qquad \text{(SLERAP Eq. F-1-3)}$$

or

$$C_{INV} = C_{IW} . BCF_W \cdot CF \qquad \text{(SLERAP Eq. 5-4)}$$

where:

C_{INV} = concentration or activity of COPCs or ROPCs in benthic invertebrate tissue (mg/kg, pCi/g)
C_{sed} = concentration or activity of COPCs or ROPCs in sediment (mg/kg, or pCi/g)
BCF_S = sediment-to-tissue bioconcentration factor for benthic invertebrates (unitless)
C_{IW} = concentration or activity of COPCs or ROPCs in sediment interstitial water (mg/L, or pCi/L), explained below
BCF_W = water-to-tissue bioconcentration factor for benthic invertebrates (L/kg)
CF = conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

When measured values were not available, the sediment-to-benthic invertebrate BCF_S are the average of all available measured bioconcentration factors, as was done for terrestrial invertebrates. For many organic COPCs, measured sediment-to-tissue BCF_S values are not available. Instead, per EPA draft guidance, values of BCF_W for organic COPCs for which no measured values were available were calculated with an equation, given in SLERAP (Eq. C-1-4) and derived by regression analysis of uptake of several organic chemicals from water by aquatic invertebrates as a function of log K_{ow} (Southworth et al. 1978). According to EPA draft guidance, it is appropriate to use a calculated concentration of an organic COPC in sediment porewater when using an aquatic BCF_W value, as calculated by the regression equation for aquatic invertebrates (SLERAP Eq. C-1-4). The concentration in sediment porewater is determined by equilibrium partitioning, which is explained in Section 8.2.3.1. Thus, the tissue EPC calculated by using the calculated BCF_W (SLERAP Eq. 5-4) will use a sediment interstitial water concentration:

$$C_{IW} = \frac{C_{sed}}{f_{oc,bs} \cdot K_{oc}} \qquad \text{(SLERAP Eq. 5-5)}$$

where:

C_{IW} = concentration of organic COPC in sediment porewater (mg/L)
C_{sed} = concentration of organic COPC in sediment (mg/kg)
K_{oc} = soil organic carbon partitioning coefficient (L/kg)
$f_{oc,bs}$ = fraction of bed sediment that is organic carbon (unitless)

Note: SLERAP Equation 5-5 first appears in Section 8.2.3.1.

The values of BCF_W for the SLERA are discussed in Section 8.2.5.4. For all COPCs and ROPCs, values for BCF_W are reported in Supplement 4.

EPCs in Aquatic Invertebrates (Trophic Level 2)

For aquatic invertebrates exposed to COPCs and ROPCs in surface water, the tissue EPC will be calculated in accordance with EPA (1999) draft guidance, using dissolved concentrations (C_{dw}) in water:

$$C_{INV} = C_{dw} \cdot BCF_{INV} \cdot CF \qquad \text{(SLERAP Eq. 5-3)}$$

where:

C_{INV} = concentration or activity of COPC/ROPC in aquatic invertebrate tissue (pCi/g)
C_{dw} = concentration or activity of COPC/ROPC dissolved in surface water (pCi/L)
BCF_{INV} = water-to-tissue uptake factor for aquatic invertebrates (L/kg)
CF = conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

For all ROPCs, values for BCF_{INV} are reported in Supplement 4.

EPCs in Fish (Trophic Levels 2, 3, and 4)

Trophic-level-specific *FCM*s will be used to calculate the concentrations of COPCs and ROPCs in fish. *FCM*s adjust the calculated concentration in fish tissue to account for bioaccumulation from one trophic level to another (see Section 8.2.5.3). For planktivorous fish (trophic level 2, FCM_2), omnivorous fish (trophic level 3, FCM_3), and carnivorous fish (trophic level 4, FCM_4) exposed to dissolved concentrations (C_{dw}) of constituents in surface water, aquatic biota, and fish, the tissue EPC will be calculated, respectively, as follows:

$$C_{F_i} = BCF_W \cdot FCM_i \cdot C_{dw} \cdot CF \qquad \text{(SLERAP Eq. 5-7)}$$

where:

C_{F_i} = concentration or activity of COPC or ROPC in fish tissue for trophic level *i* fish (mg/kg or pCi/g)
C_{dw} = concentration or activity of COPC or ROPC dissolved in surface water (mg/L or pCi/L)
BCF_W = water-to-tissue uptake factor for fish (L/kg)

FCM_i	=	food chain multiplier for trophic level *i* fish (unitless)
CF	=	conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

The values of BCF_W and *FCM*s for the SLERA are discussed in Section 8.2.5.4. For all COPCs and ROPCs, values for BCF_W are reported in Supplement 4 with values for FCM_2, FCM_3 and FCM_4.

EPCs in Mammal and Bird Tissues (Trophic Levels 2, 3, and 4)

For wildlife receptors, the tissue EPC will be calculated in accordance with EPA (1999) draft guidance as the sum of the contributions from the different types of material ingested. Trophic-level-specific *FCM*s will be used to calculate the concentrations of ROPCs in mammals and birds. The *FCM*s adjust the calculated concentration in animal tissue to account for bioaccumulation from one trophic level to another (see Section 8.2.5.3). The equations are adapted from EPA draft guidance (SLERAP Eq. 5-12),

such that the concentration in a omnivore is: (modified SLERAP Eq. 5-12)

$$C_{OM} = C_A \cdot \frac{FCM_{OM}}{FCM_A} \cdot F_A + C_{AP} \cdot BCF_P \cdot F_P + Cs_{sed} \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

and the concentration in an herbivore is: (modified SLERAP Eq. 5-11)

$$C_H = C_{AP} \cdot BCF_P \cdot F_P + Cs_{sed} \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

and the concentration in a carnivore is: (modified SLERAP Eq. 5-13)

$$C_C = C_A \cdot \frac{FCM_C}{FCM_A} \cdot F_A + Cs_{sed} \cdot BCF_S \cdot P_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

where:

$C_{OM/H/C}$	=	concentration of constituent in omnivorous, herbivorous, or carnivorous (respectively) receptor tissue (mg/kg FW tissue or pCi/g FW tissue)
C_A	=	concentration of constituent in ingested animal prey (mg/kg FW tissue or pCi/g FW tissue)
$FCM_{OM/C}$	=	food-chain multipliers for the omnivorous receptor (unitless)
FCM_A	=	food-chain multipliers for ingested prey type (unitless)
F_A	=	fraction of diet from animal tissue (unitless)
C_{AP}	=	concentration of constituent in ingested aquatic plant tissue (mg/kg plant or pCi/g plant)
BCF_P	=	plant-to-tissue uptake factor for omnivorous/herbivorous receptor (mg/kg FW tissue per mg/kg plant)
F_P	=	fraction of diet from plant tissue (unitless)
Cs_{sed}	=	concentration of constituent in ingested sediment (mg/kg or pCi/g),
BCF_S	=	soil-to-tissue uptake factor for omnivorous/herbivorous/carnivorous receptor (mg/kg FW tissue per mg/kg DW soil)

P_S	=	proportion of consumed soil or sediment that is contaminated (unitless)
C_{wctot}	=	concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)
BCF_W	=	water-to-tissue uptake factor for omnivorous/herbivorous/carnivorous receptor (mg/kg FW tissue per mg/L water)
P_W	=	proportion of consumed water that is contaminated (unitless)
CF	=	conversion factor for radionuclides, 0.001 pCi/kg to pCi/g

The plant-to-tissue uptake factors, water-to-tissue uptake factors, and soil-to-tissue uptake factors, which will be used for sediment, are calculated per EPA (1999) draft guidance from the receptor's ingestion rate and the published biotransfer factor (*Ba*), that is:

$$BCF_F = Ba \cdot IR_F \cdot BW \qquad \text{(modified SLERAP Eq. D-1-1)}$$

and:

$$BCF_M = Ba \cdot IR_M \cdot BW \qquad \text{(modified SLERAP Eq. D-1-2)}$$

where:

BCF_A	=	food-to-animal bioconcentration factor for receptor (mg COPC/kg FW tissue per mg COPC/kg FW food)
BCF_M	=	media-to-animal bioconcentration factor for receptor (mg COPC/kg FW tissue per mg COPC/kg DW media)
Ba	=	ingestion-to-tissue transfer factor (d/kg)
IR_F	=	daily food ingestion rate (kg/kg BW/d)
IR_M	=	daily media ingestion rate, such that:
IR_w	=	rate of water consumption (L/kgBW/d)
IR_S	=	$SFr \cdot IR_F$ = rate of sediment consumption (kg/kg BW/d)
SFr	=	sediment ingested per unit food ingested (unitless)
BW	=	body weight of receptor (kg)

Note: SLERAP Equations D-1-1 and D-1-2 first appear in Section 8.2.3.1.

The values of *Ba*, BCF_P, BCF_S, and BCF_W are discussed in Section 8.2.5.3 and are reported in Supplement 4. Values for IR_F, F_P, *BW*, *SFr*, and water ingestion (IR_w) for receptors exposed at that Columbia River are given in the receptor profiles in Section 8.1.3.3.

The EPCs for COPCs in aquatic plants, benthic invertebrates, and aquatic biota are used in the equations for modeling intake to aquatic ecological receptors (i.e., the ingestion *DD*). EPCs for ROPCs will be used to calculate internal radiation doses.

8.2.4.2 Modeling Intake to Aquatic Ecological Receptors

Ingestion exposure of aquatic receptors will be evaluated using exclusive diets: floating aquatic plants for the Canada goose, benthic invertebrates for the spotted sandpiper, and fish for the bald eagle and mink. Ingestion of terrestrial food items is not included because the intent is to determine the risk from COPCs and ROPCs in surface water and sediment. The ingestion *DD* (mg/kg/d) for aquatic receptors exposed to COPCs in sediment or surface water will be calculated as the sum of plant tissue, animal tissue, water, and sediment intakes:

$$DD = \sum IR_F \cdot C_i \cdot P_i \cdot F_i + \sum IR_M \cdot C_M \cdot P_M \qquad \text{(SLERAP Eq. 5-1)}$$

or:

$$DD = DD_A + DD_P + DD_{sed} + DD_W$$

where:

DD	=	daily dose by ingestion (mg/kg BW/d)
IR_F	=	receptor plant or animal food item ingestion rate (kg/kg BW-day)
C_i	=	constituent concentration in i^{th} plant or animal food item (mg/kg)
P_i	=	proportion of i^{th} food item that is contaminated (unitless) - assumed to be equal to 1
F_i	=	fraction of diet consisting of plant or animal food item *i* (unitless)
IR_M	=	media *M* ingestion rate (kg/kg BW-day [soil or bed sediment] or L/kg BW-day [water])
C_M	=	constituent concentration in media *M* (mg/kg [soil or bed sediment] or mg/L [water])
P_M	=	proportion of ingested media *M* that is contaminated (unitless)
DD_A	=	daily dose by animal ingestion (mg/kg BW/d)
DD_P	=	daily dose by plant ingestion (mg/kg BW/d)
DD_{sed}	=	daily dose by sediment ingestion (mg/kg BW/d)
DD_W	=	daily dose by water ingestion (mg/kg BW/d)

As defined by Equation 5-1 of the SLERAP:

$$DD_A = C_A \cdot IR_F \cdot F_A$$

$$DD_P = C_{TP} \cdot IR_F \cdot F_P$$

$$DD_{sed} = C_{sed} \cdot IR_F \cdot SFr$$

$$DD_W = C_{wctot} \cdot IR_W$$

where:

DD_A	=	daily dose by animal ingestion (mg/kg BW/d)
DD_P	=	daily dose by plant ingestion (mg/kg BW/d)

DD_w	=	daily dose by water ingestion (mg/kg BW/d)
DD_{sed}	=	daily dose by sediment ingestion (mg/kg BW/d)
C_A	=	concentration of constituent in ingested animal tissue (mg/kg or pCi/g)
C_P	=	concentration of constituent in ingested plant tissue (mg/kg or pCi/g)
IR_F	=	food (plant or prey, as applicable) ingestion rate of receptor (kg/kg BW/d)
IR_W	=	water ingestion rate of receptor (kg/kg BW/d)
F_A	=	fraction of diet from animals (unitless)
F_P	=	fraction of diet from plants (unitless)
C_{sed}	=	concentration of constituent in ingested sediment (mg/kg or pCi/g)
SFr	=	soil ingested per unit of food ingested (unitless)
C_{wctot}	=	concentration of constituent in water column (mg/L or pCi/L)

Proportion of contaminated food and media (P_i and P_M), absorption efficiency (AE), the area use factor (AUF), and the temporal use factor (TUF) are assumed to be equal to 1, so they do not appear in the exposure equations.

8.2.4.3 Receptor-specific Exposure Equations for Aquatic Receptors

The complete equations for DD and C_A for each receptor are presented below.

Herbivore: Canada Goose (Trophic Level 2)

Canada geese are herbivores that ingest aquatic plants, but they ingest water and sediment also with their food. Thus,

$$DD = DD_P + DD_{sed} + DD_W \text{, or} \qquad \text{(Equation 8-13)}$$

$$DD_{Goose} = C_{TP} \cdot IR_F \cdot F_P + C_{sed} \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

where DD_P, DD_W, and DD_{sed} are as given above. The Canada goose food ingestion rate (IR_F), water ingestion rate (IR_w), and dietary fractions (F_P and SFr) are given in the receptor profiles in Section 8.1.3.3. The aquatic food web (Figure 8-9) shows the prey types for the Canada goose. The Canada goose will be assumed to have an exclusive diet of aquatic plants.

Canada goose tissue concentrations of ROPCs will be calculated by an equation adapted from the SLERAP Equation 5-11:

$$C_{Goose} = C_{TP} \cdot BCF_P \cdot F_P + C_{sed} \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot P_W \cdot CF$$

where:

C_{Goose}	=	concentration in receptor tissue (mg/kg or pCi/g)
C_{TP}	=	concentration in ingested plant tissue (mg/kg or pCi/g)
F_P	=	fraction of diet from plants (unitless)
BCF_P	=	plant-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg plant)

C_{sed} = concentration of constituent in ingested sediment (mg/kg or pCi/g)

BCF_S = sediment-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg DW sediment)

C_{wctot} = concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)

BCF_W = water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)

P_w = proportion of consumed water that is contaminated (unitless)

CF = conversion factor for radionuclides, 0.001 pCi/kg to pCi/g

For ROPCs, the tissue concentration resulting from ingested water ($C_{wctot} \times BCF_W \times P_W$) must be converted from pCi/kg to pCi/g by multiplying by 0.001 kg/g. Sediment-to-tissue uptake factors (BCF_S), plant-to-tissue uptake factors (BCF_P), and water-to-tissue uptake factors (BCF_W) for the Canada goose are reported in Supplement 4.

Carnivore: Spotted Sandpiper (Trophic Level 3)

Spotted sandpipers are carnivores that ingest benthic invertebrates, but they also ingest water and sediment with their food (Figure 8-9). Thus,

$$DD = DD_A + DD_{sed} + DD_W, \text{ or} \qquad \text{(Equation 8-14)}$$

$$DD_{Piper} = C_{INV} \cdot IR_F \cdot F_A + C_{sed} \cdot IR_F \cdot SFr + C_{wctot} \cdot IR_W$$

where DD_A, DD_W and DD_{sed} are as given above. The spotted sandpiper food ingestion rate (IR_F), water ingestion rate (IR_w) and dietary fractions (F_A and SFr) are given in the receptor profiles in Section 8.1.3.3. The aquatic food web (Figure 8-9) shows the prey types of the spotted sandpiper. To evaluate exposure specifically from sediment, the spotted sandpiper is assumed to have an exclusive diet of benthic invertebrates.

Sandpiper tissue concentrations of ROPCs will be calculated by an equation adapted from EPA draft guidance (SLERAP Equation 5-13). *FCM*s (FCM_3 for trophic level 3) are used to account for bioaccumulation from ingested animal tissue. Bioaccumulation is the process whereby certain toxic substances collect in living tissues, and biomagnification is the transfer and concentration of chemicals through successive trophic levels via ingestion of prey. The *FCM* ratios are used to estimate the biomagnification for ingestion of lower trophic food by higher trophic level animals. See Section 8.2.5.3 for more details on *FCM*s.

$$C_{Piper} = C_{INV} \cdot \frac{FCM_3}{FCM_2} \cdot F_A + C_{sed} \cdot BCF_S + C_{wctot} \cdot BCF_W \cdot CF$$

where:

C_{Piper} = concentration of constituent in receptor tissue (mg/kg or pCi/g)

C_{INV} = concentration of constituent in prey tissue (mg/kg or pCi/g)

FCM_3 = food-chain multiplier for the receptor (unitless)

FCM_2 = food-chain multipliers for ingested prey type (unitless)

F_A = fraction of diet from benthic invertebrate tissue (unitless)
C_{sed} = concentration of constituent in ingested sediment (mg/kg or pCi/g)
BCF_S = sediment-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg DW sediment)
C_{wctot} = concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)
BCF_W = water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)
CF = conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

For ROPCs, the tissue concentration resulting from ingested water ($C_{wctot} \times BCF_W$) must be converted from pCi/kg to pCi/g by multiplying by a conversion factor (CF) of 0.001 kg/g. Because the diet of the spotted sandpiper is assumed to be benthic invertebrates, $F_{INV} = 1$. The *FCM*s for the sandpipers (FCM_3) and their invertebrate prey (FCM_2), along with sediment-to-tissue bioconcentration factors (BCF_S) and water-to-tissue bioconcentration factors (BCF_W), are reported in Supplement 4.

Carnivore: Great Blue Heron (Trophic Level 4)

Great blue heron are carnivores that ingest planktivorous fish, omnivorous fish, and small invertebrates, but they also ingest water with their food (Figure 8-9). The SLERA will evaluate the exposure of heron assuming ingestion of planktivorous fish (Trophic Level 2), omnivorous fish (Trophic Level 3), benthic invertebrates (Trophic Level 2), and water (Figure 8-9). Thus,

$DD = DD_A + DD_W$, or (Equation 8-15)

$$DD = C_A \cdot IR_F \cdot F_A + C_{wctot} \cdot IR_W$$

where DD_A and DD_W are as given above. In calculating the DD_A, it is assumed the heron's diet consists of 5 % Trophic Level 2 fish, 89 % Trophic Level 3 fish, and 6 % Trophic Level 2 benthic invertebrates (EPA 1993c). The expanded equation for the daily dose to the great blue heron (DD_{Heron}) is:

$$DD_{Heron} = C_{F_2} \cdot IR_F \cdot F_{F_2} + C_{F_3} \cdot IR_F \cdot F_{F_3} + C_{INV} \cdot IR_F \cdot F_{INV} + C_{wctot} \cdot IR_W$$

where C_{F_2}, C_{F_3}, C_{INV} and are the tissue concentrations of fish for Trophic Levels 2 and 3, and benthic invertebrates, respectively, as defined in Section 8.2.4.1. F_{F_2} (fraction of diet from Trophic Level 2 fish) is 0.05, F_{F_3} (fraction of diet from Trophic Level 3 fish) is 0.89, and F_{INV} (fraction of diet from benthic invertebrates) is 0.06. The great blue heron food ingestion rate (IR_F) and water ingestion rate (IR_w) are given in the receptor profiles in Section 8.1.3.3.

The aquatic food web (Figure 8-9) shows the prey types of the great blue heron.

The great blue heron tissue concentrations of ROPCs will be calculated by an equation adapted from EPA draft guidance (SLERAP Equation 5-13). *FCM*s (FCM_4 for Trophic Level 4) are used to account for bioaccumulation from ingested animal tissue:

$$C_{Heron} = C_{F_2} \cdot \frac{FCM_4}{FCM_2} \cdot F_{F_2} + C_{F_3} \cdot \frac{FCM_4}{FCM_3} \cdot F_{F_3} + C_{INV} \cdot \frac{FCM_4}{FCM_2} \cdot F_{INV} + C_{wctot} \cdot BCF_W \cdot CF$$

where:

C_{Heron}	=	concentration of in receptor tissue (mg/kg or pCi/g)
C_{F_3}	=	concentration or activity of COPC or ROPC in fish tissue for Trophic Level 3 prey type (omnivorous fish) (mg/kg or pCi/g)
C_{F_2}	=	concentration or activity of COPC or ROPC in fish tissue for Trophic Level 2 prey type (planktivorous fish) (mg/kg or pCi/g)
C_{INV}	=	concentration of in prey tissue (mg/kg or pCi/g)
FCM_4	=	food-chain multiplier for the receptor (unitless)
FCM_3	=	food-chain multipliers for ingested Trophic Level 3 prey type (omnivorous fish) (unitless)
FCM_2	=	food-chain multipliers for ingested Trophic Level 2 prey type (planktivorous fish and invertebrates) (unitless)
F_{F_3}	=	fraction of diet from Trophic Level 3 omnivorous fish (unitless)
F_{F_2}	=	fraction of diet from Trophic Level 2 planktivorous fish (unitless)
F_{INV}	=	fraction of diet from benthic invertebrate tissue (unitless)
C_{sed}	=	concentration of constituent in ingested sediment (mg/kg or pCi/g)
BCF_S	=	sediment-to-tissue uptake factor for receptor (mg/kg FW tissue per mg/kg DW sediment)
C_{wctot}	=	concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)
BCF_W	=	water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)
CF	=	conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

For ROPCs, the tissue concentration resulting from ingested water ($C_{wctot} \times BCF_W$) must be converted from pCi/kg to pCi/g by multiplying by 0.001 kg/g. Because the diet of the great blue heron is assumed to be exclusively fish and benthic invertebrates, $F_{F_3} + F_{F_2} + F_{INV} = 1$. As with other receptors, the contaminated proportion of prey is assumed to be 100 %, thus P_4 is dropped from SLERAP Equation 5-13, as presented above. The *FCM*s for the heron (FCM_4) and their planktivorous fish (FCM_2), omnivorous fish (FCM_3), and benthic invertebrate (FCM_2), and water-to-tissue bioconcentration factors (BCF_W) for the great blue heron are reported in Supplement 4.

Carnivores: Bald Eagle and Mink (Trophic Level 4)

Bald eagles and mink are carnivores that ingest omnivorous and piscivorous fish and other animals, but they also ingest water incidentally with their food (Figure 8-9). Ingestion of terrestrial prey at the Columbia River maximum site will not be evaluated because the concentrations of COPCs and ROPCs in soil near the Columbia River would be less than at the onsite ground maximum. Ingestion of terrestrial prey by red-tailed hawks will be evaluated at the onsite ground maximum, where concentrations in terrestrial prey will be higher than at the Columbia River. Because the exposure of hawks to terrestrial receptors at the onsite ground maximum is more conservative than exposure of predators to terrestrial receptors at the Columbia River, the SLERA will evaluate the exposure of mink assuming ingestion of only omnivorous fish (at Trophic Level 3) and water (Figure 8-9). However, since eagles are known to consume salmon, their dose due to prey consumption will be based on Trophic Level 4 fish consumption. Thus:

$$DD = DD_A + DD_W \text{, or} \qquad \text{(Equation 8-16)}$$

$$DD_{Eagle} = C_{F_4} \cdot IR_F \cdot F_A + C_{wctot} \cdot IR_W$$

$$DD_{Mink} = C_{F_3} \cdot IR_F \cdot F_A + C_{wctot} \cdot IR_W$$

where DD_A and DD_W are as given above, and DD_A is calculated for omnivorous fish (Trophic Level 3) and carnivorous fish (Trophic Level 4) for the mink and eagle, respectively (F_A is assumed to be 1). The eagle and mink food ingestion rates (IR_F) and water ingestion rate (IR_w) are given in the receptor profiles in Section 8.1.3.3. The aquatic food web (Figure 8-9) shows the prey types of the bald eagle and mink.

Bald eagle and mink tissue concentrations of ROPCs will be calculated by an equation adapted from EPA draft guidance (SLERAP Equation 5-13). *FCM*s (FCM_3 for Trophic Level 3) are used to account for bioaccumulation from ingested animal tissue:

$$C_{Eagle} = C_{F_4} \cdot \frac{FCM_4}{FCM_4} \cdot F_A + C_{wctot} \cdot BCF_W \cdot CF$$

$$C_{Mink} = C_{F_3} \cdot \frac{FCM_4}{FCM_3} \cdot F_A + C_{wctot} \cdot BCF_W \cdot CF$$

where:

$C_{Eagle/Mink}$	=	concentration of receptor tissue (mg/kg or pCi/g)
C_{F_4}	=	concentration of carnivorous fish (Trophic Level 4) tissue (mg/kg or pCi/g)
C_{F_3}	=	concentration of omnivorous fish (Trophic Level 3)tissue (mg/kg or pCi/g)
FCM_4	=	food-chain multipliers for the receptor (unitless)
FCM_3	=	food-chain multipliers for ingested prey type (unitless)
F_A	=	fraction of diet from omnivorous fish tissue (unitless)
C_{wctot}	=	concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)
BCF_W	=	water-to-tissue uptake factor for receptor (kg FW tissue per mg/L water)
CF	=	conversion factor of 0.001 kg/g (to convert pCi/kg to pCi/g) for ROPCs

For ROPCs, the tissue concentration resulting from ingested water ($C_{wctot} \times BCF_W$) must be converted from pCi/kg to pCi/g by multiplying by 0.001 kg/g. Because the diet of the mink and the diet of the eagle are assumed to be exclusively fish, $F_A = 1$. For the mink, a realistic diet would require the addition of a term for ingestion of plants which would result in a less conservative estimate of tissue concentration. The *FCM*s for the eagle and mink (FCM_4) and their omnivorous prey (FCM_3), and water-to-tissue bioconcentration factors (BCF_W) for the bald eagle and mink, are reported in Supplement 4.

8.2.4.4 External and Internal Radiation Dose

The total radiological dose to all receptors is calculated as the sum of the external and internal radiation doses.

$$DD = DD_E + DD_I \quad \text{(Equation 8-17)}$$

where:

DD = total radiation dose to the receptor (rad/day)
DD_E = total external radiation dose (rad/day)
DD_I = internal radiation dose (rad/day)

External doses to all aquatic biota and benthic invertebrates result from exposure to ROPCs in water and sediment. Wildlife receptors (Canada goose, sandpiper, heron, eagle, and mink) are exposed externally to ROPCs in air and water. The internal dose to plants and benthic invertebrates results from the uptake of radionuclides into their tissues from water and sediment. The internal dose to wildlife and fish receptors results from the uptake of radionuclides into their tissues from ingested food, water, and sediment. The fraction of time receptors spend immersed in sediment, on sediment, immersed in water, and in the proximity of water are scientific judgment based on narrative information about the receptors in published or internet wildlife biology articles, as given below.

External Dose

External radiation from water and sediment will be modeled as described by Blaylock, Frank, and O'Neal (1993). Radiation doses will be adjusted for the fraction of time that the receptors are assumed to be immersed in water away from sediment, or near enough to the water to receive external radiation (swimming on the surface or at the river bank), resting on sediment, and immersed in sediment. Those fractions were selected by scientific judgment based on narrative information about the receptors in published or internet wildlife articles. They are assumed to be:

	Fraction of time on/near water surface	Fraction of time immersed in water	Fraction of time resting on sediment	Fraction of time immersed in sediment
Benthic invertebrates	0	0.1	0	0.9
Aquatic biota (including plants and salmonids)	0	0.9	0.1	0
Canada goose	0.5	0	0	0
Spotted sandpiper	0.5	0	0	0
Great blue heron	0.5	0	0	0
Bald eagle	0.05	0	0	0
Mink	0.2	0	0	0

The birds and mink will also be assumed to receive external radiation from air. Note that it is assumed the Canada goose, spotted sandpiper, and great blue heron spend 50 % of the time sufficiently away from water and sediment such that there is negligible exposure due to radionuclides in the water and sediment. Likewise, the mink is assumed to spend 80 % of the time away from water and sediment, and the bald eagle spends 95 % of the time in flight or perched such that there is negligible exposure due to radionuclides in the water and sediment.

As presented in Section 8.2.3.4, the external dose (rad/day) to all receptors for a given radionuclide will be calculated as:

$$DD_E = \Sigma(\text{ROPC Concentration} \cdot \text{Dose Conversion Factor})$$

where DD_E is the external radiation dose (rad/day). The external doses (rad/day) to all aquatic receptors from water, sediment, and air will be calculated, respectively, as follows:

$$DD_E = DD_{E_{water}} + DD_{E_{sed}} + DD_{E_{air}}$$

where:

DD_E = total external radiation dose (rad/day)

$DD_{E_{water}}$ = external radiation dose from immersion in water (rad/day)

$DD_{E_{sed}}$ = external radiation dose from sediment (rad/day)

$DD_{E_{air}}$ = external radiation dose from air (rad/day)

The external dose from water exposure includes both immersion and time spent on or near the water surface. The external daily dose due to water proximity and contact is:

$$DD_{E_{water}} = DD_{near} + DD_{imm}$$

where:

$DD_{E_{water}}$ = external radiation dose from water (rad/day)

DD_{near} = external dose from exposure on or near water (rad/day)

DD_{imm} = external dose from exposure due to water immersion (rad/day)

Receptors immersed in water will be exposed to beta and gamma radiation. Receptors on the surface or in direct proximity to water will receive exposure to gamma radiation. Alpha radiation (for both near water and immersion exposures) and beta radiation (for near water exposures) are not assumed to contribute to the external dose factor because they do not penetrate enough to cause exposure. For example, Sr-90 and Sr-92 both have beta radiation with an energy of 0.196 MeV; Sr-90 has no gamma radiation, whereas Sr-92 has gamma radiation. The *DCF* associated with a 15-cm thick soil source for Sr-90 is 3.72E-21 Sv/s per Bq/m^3, whereas the *DCF* for Sr-92, under the same scenario, is 3.88E-17 Sv/s per Bq/m^3. In this case, the external beta radiation causes only about 1/10,000 of the dose. Similarly, for alpha radiation, Sm-146, Sm-147, Gd-148, and Gd-152 have alpha radiation but neither beta nor gamma, thus their *DCF*s are 0.

The external dose for water immersion (DD_{imm}) and near or surface water contact (DD_{near}) is derived from Blaylock, Frank, and O'Neal (1993) and is calculated as:

$$DD_{near} = F_{near} \cdot E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right) \cdot CFa \cdot CF \cdot C_{wctot}$$ (Blaylock et. al. (1993), Eq. 2)

$$DD_{imm} = F_{imm} \cdot \left[E_{\beta} \cdot \left(1 - AbF_{\beta}\right) + E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right)\right] \cdot CFa \cdot CF \cdot C_{wctot}$$ (Blaylock et. al. (1993), Eqs. 2 and 6)

Factoring C_{cwtot}, substituting variables to represent the dose factor yields the following equations:

$$DD_{E_{water}} = \left(F_{near} \cdot E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right) \cdot CFa \cdot CF + F_{imm} \cdot \left[E_{\beta} \cdot \left(1 - AbF_{\beta}\right) + E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right)\right] \cdot CFa \cdot CF\right) \cdot C_{wctot}\text{ , or}$$

$$DD_{E_{water}} = \left(DCF_{near} + DCF_{imm}\right) \cdot C_{wctot}\text{ , or}$$

$$DD_{E_{water}} = DCF_{water} \cdot C_{wctot}$$

Thus, the external dose to an aquatic receptor due to water exposure to a ROPC will be calculated according to:

$$DD_{E_{water}} = DCF_{water} \cdot C_{wctot}\text{ , and}$$

$$DF_{water} = \left[\left(F_{near} + F_{imm}\right) \cdot E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right) + F_{imm} \cdot E_{\beta} \cdot \left(1 - AbF_{\beta}\right)\right] \cdot CFa \cdot CF$$

where:

$DD_{E_{water}}$	=	external radiation dose from water (rad/day)
DCF_{water}	=	factor for converting activity of radionuclide in water to external dose from exposure to water in units of rad/day per pCi/g ($DCF_{water} = DCF_{near} + DCF_{imm}$)
DCF_{near}	=	factor for converting activity of radionuclide in water to external dose from exposure near water, or due to surface water in units of rad/day per pCi/g ($DCF_{near} = F_{near} \cdot E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right) \cdot CFa \cdot CF$)
DCF_{imm}	=	factor for converting activity of radionuclide in water to external dose from immersion water, in units of rad/day per pCi/g ($DCF_{imm} = F_{imm} \cdot \left[E_{\beta} \cdot \left(1 - AbF_{\beta}\right) + E_{\gamma} \cdot \left(1 - AbF_{\gamma}\right)\right] \cdot CFa \cdot CF$)
F_{imm}	=	fraction of time receptor spends immersed in water (unitless)
F_{near}	=	fraction of time receptor spends near or swimming on the surface of the water (unitless)
AbF_{β}	=	absorbed fraction of energy from beta energy E_{β} (unitless)
E_{β}	=	average energy emitted as beta radiation × proportion of disintegrations producing a beta-particle (MeV per disintegration)
AbF_{γ}	=	absorbed fraction of energy from gamma energy E_{γ} (unitless)

E_γ	=	photon energy emitted during transition from a higher to a lower energy state × proportion of disintegrations producing gamma radiation (MeV/disintegration)
CFa	=	unit conversion factor, 5.12×10^{-5} rad/day per pCi/g per MeV/disintegration
CF	=	factor to convert L to g (0.001 L/ml × 1 ml/g = 0.001 L/g)
C_{wctot}	=	concentration of constituent in unfiltered water from Columbia River maximum location (mg/L or pCi/L)

AbF_γ and E_γ for each ROPC are reported in Supplement 4 for all ROPCs. To calculate external exposure to all aquatic receptors from ROPCs in water, DCF_{water} values will be multiplied by the modeled total activities of the corresponding radionuclides in surface water at the Columbia River maximum location. The external dose from sediment exposure includes both exposure to the water/sediment interface, and time spent buried in the sediment. The external daily dose due to sediment immersion and contact is:

$$DD_{E_{sed}} = DD_{s/w} + DD_{sed,imm}$$

where:

$DD_{E_{sed}}$	=	external radiation dose from soil (rad/day)
$DD_{s/w}$	=	external dose from exposure on sediment/water interface (rad/day)
$DD_{sed,imm}$	=	external dose from exposure due to immersion in sediment (rad/day)

Following the logic of Blaylock, Frank, and O'Neal (1993), the external dose for sediment contact ($DD_{s/w}$) and sediment immersion ($DD_{sed,imm}$) will be calculated as:

$$DD_{s/w} = 0.5F_{s/w} \cdot \left[E_\beta \cdot (1 - AbF_\beta) + E_\gamma \cdot (1 - AbF_\gamma)\right] \cdot CFa \cdot C_{sed}$$ (Blaylock et. al. (1993), Eqs. 3 and 7)

$$DD_{sed,imm} = F_{sed,imm} \cdot \left[E_\beta \cdot (1 - AbF_\beta) + E_\gamma \cdot (1 - AbF_\gamma)\right] \cdot CFa \cdot C_{sed}$$ (Blaylock et. al. (1993), Eqs. 2 and 6)

Factoring C_{sed}, substituting variables to represent the dose factor yields the following equations:

$$DD_{E_{sed}} = \begin{pmatrix} 0.5F_{s/w} \cdot \left[E_\beta \cdot (1 - AbF_\beta) + E_\gamma \cdot (1 - AbF_\gamma)\right] \cdot CFa + \\ F_{sed,imm} \cdot \left[E_\beta \cdot (1 - AbF_\beta) + E_\gamma \cdot (1 - AbF_\gamma)\right] \cdot CFa \end{pmatrix} \cdot C_{sed} \text{ or}$$

$$DD_{E_{sed}} = (DCF_{s/w} + DCF_{sed,imm}) \cdot C_{sed}\text{, or}$$

$$DD_{E_{sed}} = DCF_{sed} \cdot C_{sed}$$

Thus, the external dose to an aquatic receptor due to sediment exposure to a ROPC will be calculated according to:

$$DD_{E_{sed}} = DCF_{sed} \cdot C_{sed}\text{, and}$$

$$DCF_{sed} = \left(0.5F_{s/w} + F_{sed,imm}\right)\cdot\left[E_\beta\cdot\left(1-AbF_\beta\right)+E_\gamma\cdot\left(1-AbF_\gamma\right)\right]\cdot CFa\cdot C_{sed}$$

where:

$DD_{E_{sed}}$	=	external radiation dose from soil (rad/day)
DCF_{sed}	=	factor for converting activity of radionuclide in sediment contact and immersion to external dose from exposure to the sediment in units of rad/day per pCi/g ($DCF_{sed} = DCF_{s/w} + DCF_{sed,imm}$)
$DCF_{s/w}$	=	factor for converting activity of radionuclide in sediment/water interface to external dose from exposure to the sediment/water interface in units of rad/day per pCi/g ($DCF_{s/w} = 0.5F_{s/w}\cdot\left[E_\beta\cdot\left(1-AbF_\beta\right)+E_\gamma\cdot\left(1-AbF_\gamma\right)\right]\cdot CFa$)
$DCF_{sed,imm}$		= factor for converting activity of radionuclide in sediment to external dose from exposure due to burial in sediment, in units of rad/day per pCi/g ($DCF_{sed,imm} = F_{sed,imm}\cdot\left[E_\beta\cdot\left(1-AbF_\beta\right)+E_\gamma\cdot\left(1-AbF_\gamma\right)\right]\cdot CFa$)
0.5	=	factor to account for assumption that a receptor at the sediment-water interface receives external radiation from sediment only from below, so the dose is only half of the dose from immersion (unitless)
$F_{s/w}$	=	fraction of time receptor spends at the sediment-water interface (unitless)
F_{sed}	=	fraction of time receptor spends buried in sediment (unitless)
E_β	=	average energy emitted as beta radiation × proportion of disintegrations producing a β-particle (MeV per disintegration)
AbF_β	=	absorbed fraction of energy from beta energy E_β (unitless)
E_γ	=	photon energy emitted during transition from a higher to a lower energy state (MeV) × proportion of disintegrations producing γ radiation (MeV/disintegration)
AbF_γ	=	absorbed fraction of energy from gamma energy E_γ (unitless)
CFa	=	unit conversion factor, 5.12×10^{-5} rad/day per pCi/g per MeV/disintegration

Immersion in sediment exposes receptors to a static, direct-contact interface with the contaminated media. Accordingly, a portion of the external dose while immersed in sediment can be attributed to radionuclide daughter products. Because immersion air and river water are not static (i.e., the air and water are in continuous motion), the impact of daughter products is assumed to be insignificant due to limited non-static contact. Terrestrial exposure due to soil contact is not considered a direct-contact interface (that is, continuous and complete immersion of the receptor is disrupted by air and vegetation because of the nature of burrows and dens). Therefore, the external dose due to daughter products in soil is assumed to be negligible.

The exposures of aquatic receptors to ROPCs in sediment is calculated by assuming that the decay products of all short-lived ROPCs in sediment are in secular equilibrium. The activities of each of the daughter radionuclides are, therefore, equal to the activity of the parent multiplied by the fraction of the decays in the immediately preceding generation that yield the daughter radionuclide.

$$DCF_D = DCF_{parent}\cdot y$$

where

DCF_D = the dose factor of the daughter product
DCF_{parent} = the dose factor of the parent isotope
y = yield of the daughter product from the decay of the parent isotope (percent)

For example, the activities of radium-225, actinium-225, francium-221, astatine-217, and bismuth-213 are assumed to be equal to the activity of their parent, thorium-229. However, when bismuth-213 decays, 97.8 % of the decays yield polonium-213 and 2.2 % of the decays yield thallium-209. Therefore, the activities of polonium-213 and thallium-209 are assumed to be 97.8 % and 2.2 %, respectively, of the activity of thorium-229. Exposure factors for the daughter radionuclides were used to calculate the summed exposures from the ultimate parent and all of the daughter radionuclides for both external and internal radiation from exposure to sediments; thus, for an ROPC that undergoes decay:

$$DCF_{sed+D} = DCF_{sed_{parent}} + \sum_{i=1}^{n} DCF_{sed_D}$$

where

DCF_{sed+D} = factor for converting activity of radionuclide (and its daughter products) to external dose from exposure to the sediment in units of rad/day per pCi/g
$DCF_{sed_{parent}}$ = factor for converting activity of the parent radionuclide to external dose from exposure to the sediment in units of rad/day per pCi/g
$\sum_{i=1}^{n} DCF_{sed_D}$ = sum of the daughter product dose factors for each applicable daughter product (1 through *n*) for converting activity of the daughter product to external dose from exposure to the sediment in units of rad/day per pCi/g

The dose factor for each daughter product is calculated using the energy (E) and absorption factor (AbF) appropriate to the daughter product in accordance with the equations above. The fraction of time a receptor spends immersed in water, near the water, or swimming on the surface of the water must also be applied when computing the contribution of daughter products to a ROPC dose factor.

Values of $F_{s/w}$ and F_{sed} are reported in Supplement 4 along with AbF_β, E_β, AbF_γ, and E_γ for all ROPCs and their daughters. To calculate external exposure to all aquatic receptors from ROPCs in water and sediment, DCF_{water} and DCF_{sed}, values will be multiplied by the modeled activities of the corresponding radionuclides in surface water and sediment at the Columbia River maximum location.

Per EPA (1993c or Eckerman and Ryman 1993), the external dose (rad/day) to all wildlife receptors from air will be calculated as:

$$DCD_{E_{air}} = DCF_{air} \cdot C_a$$

where:

$DD_{E_{air}}$ = external radiation dose from air (rad/day)

C_a = activity of the ROPC in air, calculated as described in Section 6.1 (pCi/m^3)

DCF_{air} = factor for converting activity of the ROPC in air to external dose from air (rad/day per pCi/m^3

Note: This equation first appears in Section 8.2.3.4.

The external dose conversion factor for air (DCF_{air}) will be calculated as follows:

$$DCF_{air} = 3.2 \times 10^5 \cdot DCF$$

where:

3.2×10^5 = conversion factor to convert Sv/s per Bq/m^3 to rad/day per pCi/m^3 (Eckerman and Ryman 1993)

DCF = dose conversion factor for external radiation from immersion in air (Sv/s per Bq/m^3, Eckerman and Ryman 1993)

Note: The equation for DCF_{air} first appears in Section 8.2.3.4.

For all ROPCs, values of *DCF* for air are reported in Supplement 4. To calculate external exposure to all aquatic receptors from ROPCs in air, *DCF* values will be multiplied by the modeled activities of the corresponding radionuclides in air at the Columbia River maximum location.

Internal Dose

The internal exposure to radionuclides is calculated from the activity in tissues rather than from the daily ingestion. The internal activities of ROPCs are calculated by using *BCF*s and ROPC activities in sediment, food, and water (see Section 8.2.4.3). Internal radiation doses are calculated by multiplying the activity in tissues by the sum of alpha, beta, and gamma decay energies, where alpha and beta energies are assumed to be completely absorbed. Because gamma rays, like X-rays, may pass through the tissues without depositing their energy, gamma energies are adjusted to account for greater absorption by larger organisms at a given energy level and for greater absorption by all receptors at lower energy levels. For radionuclides in sediment, radiation by daughter radionuclides was also included in internal dose calculations. Daughter radionuclides are produced by decay of parent radionuclides and short-lived radionuclides could be expected to contribute to the receptor's internal dose. As previously discussed, exposures are calculated by assuming that the decay products of all short-lived ROPCs are in secular equilibrium and equal to the activity of the parent multiplied by the fraction of the decays in the immediately preceding generation that yielded the daughter radionuclide. Decay energies (Eckerman and Ryman 1993) and absorption fractions for gamma radiation (Blaylock, Frank, and O'Neal 1993; Sample et al. 1997) of daughter radionuclides are reported in Supplement 4.

Adapting the equations of Sample et al. (1997), the internal dose (rad/day) to aquatic receptors and wildlife receptors will be calculated as follows:

$$DD_I = \sum QF \cdot C_{AP \text{ or } INV \text{ or } A} \cdot E \cdot CF \cdot AbF \qquad \text{(modified Sample et al. (1997), Eq. 11)}$$

where

DD_I	=	internal radiation dose (rad/day)
QF	=	quality factor for relative biological effect of radiation (unitless) (Kocher and Trabalka 2000)
QF_α	=	10 for alpha radiation
QF_β	=	1 for beta radiation
QF_γ	=	1 for beta radiation
$C_{AP \text{ or } INV \text{ or } A}$	=	activity of radionuclide in receptor tissue (aquatic plant, benthic invertebrate, or animal - see Section 8.2.4.3) (pCi/g)
CF	=	unit conversion factor, 5.12×10^{-5} rad/day per pCi/g per MeV/disintegration
E	=	average energy emitted as alpha, beta, or gamma radiation by radionuclide i × proportion of disintegrations producing alpha, beta, or gamma radiation (MeV per disintegration)
AbF	=	absorbed fraction of energy from alpha, beta, or gamma energy (unitless)

The equation above can be expanded to show the variables specific to the types of radiation emitted from the ROPC.

$$DD_I = \left(QF_\alpha \cdot E_\alpha \cdot AbF_\alpha + QF_\beta \cdot E_\beta \cdot AbF_\beta + QF_\gamma \cdot E_\gamma \cdot AbF_\gamma\right) \cdot CF \cdot C_{AP \text{ or } INV \text{ or } A}$$

Substituting variables to represent the dose factor yields:

$$DD_I = DCF_I \cdot C_{AP \text{ or } INV \text{ or } A}\text{, and}$$

$$DF_I = \left(QF_\alpha \cdot E_\alpha \cdot AbF_\alpha + QF_\beta \cdot E_\beta \cdot AbF_\beta + QF_\gamma \cdot E_\gamma \cdot AbF_\gamma\right) \cdot CF$$

where QF_α, QF_β, and QF_γ are the quality factors of alpha, beta, and gamma radiation (respectively), E_α, E_β, and E_γ are the product of the average energy emitted and proportion of disintegrations producing alpha, beta, and gamma radiation (respectively), and AbF_α, AbF_β, and AbF_γ are absorbed fraction of energy from alpha, beta, and gamma energy (respectively). Other terms are as defined above. Note that these equations first appear in Section 8.2.3.4. As with sediment exposures, internal exposure dose factors for aquatic receptors include the contribution of daughter products:

$$DCF_{I+D} = DCF_{I_{parent}} + \sum_{i=1}^{n} DCF_{I_D}$$

where

DCF_{I+D} = factor for converting activity of radionuclide (and its daughter products) to internal dose from ingestion of contaminated food in units of rad/day per pCi/g

$DCF_{I_{parent}}$ = factor for converting activity of the parent radionuclide to internal dose from exposure in units of rad/day per pCi/g

$\sum_{i=1}^{n} DCF_{I_D}$ = sum of the daughter product dose factors for each applicable daughter product (1 through n) for converting activity of the daughter product to internal dose in units of rad/day per pCi/g

Values of E and AbF for each radiation (alpha, beta and gamma) are reported in Supplement 4 for all ROPCs and their daughters, respectively. To calculate internal exposure to all aquatic receptors from ingested ROPCs, DCF_I values will be multiplied by the modeled activities of the corresponding radionuclides in receptor tissues at the Columbia River maximum location.

8.2.5 Exposure Variables

The magnitude of exposure of ecological receptors to COPCs and ROPCs in environmental media depends on various parameters and variables in the above exposure equations. These variables are discussed in this section. The exposure variables include space and time factors correcting for the fraction of a receptor's total exposure that can originate at the exposure location (Section 8.2.5.1), variables determining the rate of ingestion and absorption of COPCs and ROPCs (Section 8.2.5.2), and factors accounting for the accumulation in tissues of substances present in exposure media or food (Section 8.2.5.3). The exposure variables for ecological receptors are briefly discussed below.

8.2.5.1 Space and Time Factors for Exposure Calculations

For wildlife receptors that are exposed to COPCs and ROPCs by ingestion and inhalation, the calculation of exposure requires exposure factors that quantify the fraction of a receptor's exposure obtained from the contaminated site. A receptor may obtain only a fraction of its exposure to a contaminant from the exposure location as a result of the receptor foraging over an area larger than the exposure location or spending only a fraction of its lifetime at the exposure location, or both. The exposure assumptions for use and derivation of area-use and temporal-use factors follow.

Area-Use Factor

The area-use factor (AUF) estimates the fraction of a receptor's exposure that comes from the exposure location. The AUF is the smaller of 1 and the ratio of the area of the exposure location and the area in which a receptor lives or forages, whichever is more appropriate to the routes by which the receptor is exposed. The AUF is calculated as follows:

$$AUF = 1\text{, if } A \geq HR$$

$$AUF = A/HR\text{ , if } A < HR$$

where:

AUF = area use factor (unitless)

A = area of exposure (ha)

HR = home range of the receptor (ha)

For the SLERA, the *AUF* will be assumed to be 1 for all receptors. This assumption is highly conservative for wide-ranging receptors such as mule deer, coyote, red-tailed hawk, and bald eagle.

Temporal-Use Factor

There are several approaches to dealing with the temporal aspect of exposure. The first approach is to assume, conservatively, that receptors are exposed throughout their lifetime to COPCs and ROPCs present at the exposure location. The second approach is to estimate the temporal-use factor (*TUF*) as the fraction of time each year that a receptor is in the vicinity of the exposure location during which it forages or resides at the exposure location. The remaining time is assumed to be spent in an area free of contamination from the source being evaluated.

For the SLERA, the *TUF* will be assumed to be 1 for all receptors. This assumption is appropriate because some species at each trophic level are nonmigratory year-round residents, even if the specific receptor species evaluated may not be.

8.2.5.2 Uptake Variables

The exposure equations for ecological receptors include parameters for body weight, the ingestion rate, and dietary distribution of ecological receptors and the efficiency of absorption of COPCs and ROPCs from ingested media. Where possible, data was taken from published sources (especially EPA 1993a, 1999) and Sample et al. (1997). In some cases, measured values were not available. However, EPA 1993a provides allometric equations that allow various intake parameters to be calculated from the receptor's body weight. These equations were derived by fitting curves to the measured parameters for animals with various body weights but with similar metabolic characteristics. Such parameters as total food ingestion and water ingestion depend on the caloric requirements and metabolic rate of the receptor, both of which are related to body weight. Allometric equations were used to calculate the water ingestion rates for the mourning dove and western meadowlark and the total food ingestion rates for the mourning dove and spotted sandpiper. Source data included allometric calculations of the food ingestion rate of the great blue heron and water ingestion rates of coyote, red-tailed hawk, Canada goose, spotted sandpiper, great blue heron, bald eagle, and mink. Uptake variables are shown in the receptor parameter descriptions in Section 8.1.3.3.

Ingestion Rates

The magnitude of exposure of ecological receptors to COPCs and ROPCs in environmental media depends on the rate of intake of the contaminated media. For wildlife receptors exposed by ingestion, receptor-specific ingestion rates are required to estimate exposure. Published values for food ingestion (IR_F), soil and sediment fraction (*SFr*), and water ingestion (IR_W) will be used to estimate exposure.

Absorption Efficiency

Substances ingested or inhaled by ecological receptors are absorbed and taken up into the receptor's cells and organs to varying degrees. The efficiency of absorption depends on the relative affinity of the substance for the environmental medium (soil, particulate, sediment, water, and tissue) and on the relative affinity of the substance for the receptor's tissues. For both the PRA and the FRA, the absorption efficiency (*AE*) for ingested media will be assumed to be the same as or 100 % of the actual absorption of the contaminant in the experiment or field observation used to derive the TRV. Therefore, *AE* does not appear in the exposure equations. This assumption is conservative for COPCs and ROPCs ingested as soil, sediment, or particulates in water.

8.2.5.3 Bioconcentration Factors for Calculating Terrestrial Exposures

The calculation of exposure for ecological receptors may require one or more bioaccumulation and transfer factors. These factors are used to estimate the concentration in the tissue of an organism from the concentrations in the contaminated media to which it is exposed. Such factors are required to estimate exposure for wildlife receptors, such as mammals and birds, that are exposed to COPCs and ROPCs in soil or water by ingestion of soil, water, plants, or soil-dwelling invertebrates or other wildlife when the concentration in the ingested organism is not measured directly (Figure 8-12). In each case, the numerator of the factor must have units corresponding to the units of concentration in the medium taking up the substance (tissue), and the denominator must have units corresponding to the units of concentration in the "source" medium (soil, water, or tissue). The rules for use and derivation of bioaccumulation or transfer factors follow:

Direct Deposition-to-Plant Tissue Transfer Factor

The uptake of COPCs and ROPCs by direct deposition to leaf surfaces, including transfer factors, is discussed in Section 6.6.1.

Air-to-Plant Tissue Transfer Factor

The uptake of COPCs in vapor, including transfer factors, is discussed in Section 6.6.2.

Soil-to-Plant Bioconcentration Factor

The concentration in aboveground portions of plants through root uptake from soil is a function of the COPC- and ROPC-specific soil concentration (see Section 8.2.3.1) and COPC- or ROPC-specific plant *BCF*. The *BCF* is the ratio of the COPC or ROPC concentration in plant tissue to the COPC or ROPC concentration in soil. The *BCF* will be used to estimate the tissue concentration in plants exposed to COPCs and ROPCs in soil from the concentration of COPC or ROPC in bulk soil. The exposure evaluation will consider three kinds of *BCF*: measured or empirically derived values, mass-limited values, and bioaccumulation equivalency factors (*BEF*s), as well as methods to calculate concentrations of carbon-14 and tritium in plants.

Measured or Empirically Derived Values. When measured or empirically derived *BCF*s are used, the concentrations of COPCs and ROPCs from soil in plant tissue are proportional to the concentrations in soil. That is:

$$BCF_r = \frac{C_{TP}}{C_M} \qquad \text{(SLERAP Eq. 5-2)}$$

where:

BCF_r = bioconcentration factor (unitless [soil, sediment], or L/kg [water])
C_{TP} = constituent concentration in plant (mg/kg or pCi/g)
C_M = constituent concentration in media (mg/kg or pCi/g [soil, sediment], or mg/L or pCi/L [water])

Concentrations are estimated for plant tissues that are fed upon by wildlife receptors.

Values of BCF_r are reported in Supplement 4. The first choice for BCF_r values will be EPA (1999) values, and values developed using EPA methods. Per EPA draft guidance (1999), values of BCF_r for organic COPCs for which no field or laboratory data is available are estimated using the Travis and Arms (1988) regression on K_{ow}:

$$\log BCF_r = 1.588 - (0.578 \times \log \mathrm{K_{ow}}) \qquad \text{(SLERAP Eq. C-1-2)}$$

K_{ow} and log K_{ow} values are reported in Supplement 4. Where K_{ow} values were not available, they were calculated by using EPA's EPI Suite ™ software, which calculates physical properties of organic chemicals from structure/activity relationships.

Travis and Arms (1988) measured soil-to-plant uptake values for 29 organic chemicals (primarily pesticides) to establish a linear relationship between these two parameters. The equations used to calculate *BCF*s rely on empirical data from a few chemicals, plants, and growing media to extrapolate to all other organic chemicals and growing situations. As noted by EPA (1999), this regression equation, derived from experiments conducted on three classes of compounds (pesticides, PCDDs, and PCBs), may not accurately represent the behavior of all organic COPCs under site-specific conditions, and further research is needed to evaluate the applicability and limitations associated with the use of this equation for all classes of compounds.

Per EPA draft guidance (1999), recommended BCF_r values for inorganic elements are values published in Baes et al. (1984), Cappon (1981), and EPA (1992, 2005). For inorganic COPCs and ROPCs with no published measured or estimated data, the arithmetic average of the available BCF_r values for the other inorganics will be used as the *BCF* (EPA 1999).

Mass-Limited Values. In some cases, Equation C-1-2 in the SLERAP (Travis and Arms 1988) predicts the accumulation in plants of more organic COPC than is deposited on the soil (see Section 6.6.3.3 for a detailed discussion). Mass-limited *BCF* caps were derived for organic COPCs by (1) assuming that all of the COPC emitted from the WTP and deposited on the soil is taken up by the plants, (2) calculating the concentration of COPC in all of the plants in 1 m^2, and (3) dividing that concentration by the concentration of COPC in the soil if all of the COPC is mixed in the rooting zone, which is the upper 15 cm.

The maximum possible uptake factor is calculated as shown in the following equations:

$$\begin{array}{c}\text{Maximum possible}\\ \text{bioconcentration factor}\end{array} = \frac{\text{Total COPC deposited (mg/m}^2\text{) / Plant mass density (kg/m}^2\text{)}}{\text{Total COPC deposited (mg/m}^2\text{) / Soil density (kg/m}^2\text{)}}$$

This equation can be reduced to:

$$\begin{array}{c}\text{Maximum possible}\\ \text{bioconcentration factor}\end{array} = \frac{\text{Soil density (kg soil/m}^2\text{)}}{\text{Plant mass density (kg plant/m}^2\text{)}} \qquad \text{(Equation 8-19)}$$

The mass of soil per m^2 is 1300 kg/m^3 × 15 cm = 195 kg/m^2. The mass of plants used as food for herbivores is assumed to be the yield of forage, which is 0.15 kg/m^2. A plant yield value 0.15 kg/m^2 for forage was derived from a value of 1,500 kg/ha dry yield for Richland, Washington (Wisiol 1984, refer to

Table 6-5). Therefore, the mass-limited BCF_r is 195/0.15 = 1300. All of the published or calculated values of BCF_r presented in Supplement 4 are less than that upper limit, so the mass-limited BCF_r was not used.

Bioconcentration Equivalency Factors. The EPA recommends using *BEF*s to estimate the bioconcentration of PCDD and PCDF congeners for which field or laboratory measurements are not available. The BEF is the predicted ratio of bioaccumulation of a PCDD or PCDF congener in soil to the bioaccumulation of 2,3,7,8-tetrachlorodioxin (TCDD) (EPA 1999). *BEF*s were used by EPA (1999) to calculate the values for *BCF* presented in Supplement 4 for PCDD and PCDF congeners.

$$BCF_i = BCF_{TCDD} \cdot BEF_i \qquad \text{(SLERAP Eq. 2-6)}$$

where:

BCF_i = media-to-animal or media-to-plant bioconcentration factor for i^{th} congener (L/kg [water], unitless [soil and sediment])

BCF_{TCDD} = media-to-receptor *BCF* for 2,3,7,8-TCDD (L/kg [aquatic receptor], unitless [soil and sediment receptor])

BEF_i = bioaccumulation equivalency factor for i^{th} congener (unitless)

Carbon-14 and Tritium. *BCF*s are used for all ROPCs except carbon-14 and tritium. Exposure calculations for most ROPCs are based on the assumption that radionuclides are present as particulates or vapors. However, special consideration must be given to carbon-14 and tritium (hydrogen-3), as these ROPCs are processed by vegetation with natural carbon and hydrogen, respectively. Thus, the vegetation pathways for carbon-14 and tritium are dependent on the exchange of carbon and hydrogen between plants and the environment. For this assessment, guidance from Regulatory Guide 1.109 (NRC 1977) is used to account for the bioaccumulation of carbon-14 and tritium in plants. This is done through the use of correction factors, along with the assumption that all carbon-14 is released by the WTP in oxide form (CO or CO_2) and tritium is released as water vapor. These correction factors are applied to the air concentration (e.g., pCi/m^3) estimated at the point of exposure by the air model.

The concentration of carbon-14 in vegetation is calculated assuming that its ratio to the natural carbon in vegetation is equal to the ratio of carbon-14 to natural carbon in the atmosphere surrounding the vegetation as described in Section 6.6.2.

The concentration of tritium in vegetation is based on the equilibrium between moisture in the air and water in plants as described in Section 6.6.2.

Soil-to-plant uptake values are also used for aboveground protected and unprotected plant parts for human health exposure (Section 6.6.3).

Soil-to-Terrestrial Invertebrate Bioconcentration Factor

The concentration in terrestrial invertebrates through uptake from soil is a function of the COPC- or ROPC-specific soil concentration (see Section 8.2.3.1) and COPC- or ROPC-specific invertebrate BCF_S. The BCF_S is the ratio of the COPC or ROPC concentration in invertebrate tissue to the COPC or ROPC concentration in soil. The BCF_S will be used to estimate the tissue concentration in invertebrates exposed to COPCs and ROPCs in soil from the concentration of COPC or ROPC in bulk soil. The exposure evaluation will consider two versions of BCF_S: measured or empirically determined values and mass-limited values.

Measured or Empirically Determined Values. The soil-to-terrestrial invertebrate tissue transfer factor (BCF_S) is the ratio of the COPC or ROPC concentration in terrestrial invertebrate tissue to the COPC or ROPC concentration in soil [(mg/kg$_{\text{tissue}}$ wet wt)/(mg/kg$_{\text{soil}}$ dry wt)]. The BCF_S is used to estimate the tissue concentration of terrestrial invertebrates exposed to COPCs and ROPCs in soil by all exposure routes (ingestion, direct contact, and inhalation) from the concentration of a COPC or ROPC in bulk soil. That is:

$$BCF_{INV} = \frac{C_{INV}}{C_M} \qquad \text{(SLERAP Eq. 5-2)}$$

where:

BCF_{INV}	=	bioconcentration factor (unitless [soil, sediment], or L/kg [water])
C_{INV}	=	constituent concentration in the terrestrial invertebrate (mg/kg or pCi/g)
C_M	=	constituent concentration in media (mg/kg or pCi/g [soil, sediment], or mg/L or pCi/L [water])

BCF_{INV} is used for soil-dwelling invertebrates, such as worms or insects, that are an important diet item of many omnivores, such as pocket mice and meadowlarks. Tissue concentrations will be estimated for terrestrial invertebrates that are fed upon by wildlife receptors. Although the habitat at most of the Hanford Site is not favorable to earthworms, earthworms are used as a representative of soil invertebrates because most of the data about soil invertebrates pertain to earthworms. This is consistent with EPA draft guidance (EPA 1999), which uses measured uptake factors for earthworms to represent all soil invertebrates.

The first choice for terrestrial soil-to-soil invertebrate bioaccumulation (BCF_{INV}) values will be field or laboratory values and calculated values for earthworms reported by EPA (1999). Per EPA draft guidance (1999), recommended BCF_{INV} values for inorganic elements with no published field or laboratory data is arithmetic averages of the BCF_{INV} values available for other inorganics. For organic compounds with no field or laboratory data, BCF_{INV} values will be calculated with a regression equation described by EPA (1999):

$$\log BCF_{INV} = 0.819 \times \log K_{ow} - 1.146 \qquad \text{(SLERAP Eq. C-1-1)}$$

This equation uses values derived from K_{ow}s and uptake by daphnids, an aquatic macroinvertebrate, exposed to polycyclic aromatic hydrocarbons (PAHs) (Southworth et al. 1978). Where no appropriate published surrogate data is available, no default BCF_{INV} for organic compounds is used.

The BCF_{INV} values are listed in Supplement 4. Note that the earthworm data serves as proxy for the darkling beetle and other desert terrestrial invertebrates for which there are no known BCF_{INV} values.

Mass-Limited Values. In some cases, BCF_{INV} predicts the accumulation in soil invertebrates of more COPC than is deposited on the soil. Mass-limited BCF_{INV} values were derived for organic COPCs by (1) assuming that all of the COPC is taken up by the soil invertebrates, (2) calculating the concentration of COPC in all of the soil invertebrates in 1 m^2, and (3) dividing that concentration by the concentration of COPC in the soil if all of the COPC is mixed in the rooting zone, which is the upper 15 cm. The maximum possible uptake factor can be calculated by assuming that all of the COPC deposited in a unit area of soil in a specified time period is taken up into the mass of soil invertebrates contained in that area as shown in the following equation.

$$\text{Maximum possible bioconcentration factor} = \frac{\text{Total COPC deposited (mg/m}^2\text{) / Soil invertebrate mass density (kg/m}^2\text{)}}{\text{Total COPC deposited (mg/m}^2\text{) / Soil density (kg/m}^2\text{)}}$$

This equation can be reduced to:

(Equation 8-20)

$$\text{Maximum possible bioconcentration factor} = \frac{\text{Soil density (kg soil/m}^2\text{)}}{\text{Soil invertebrate mass density (kg soil invertebrate/m}^2\text{)}}$$

The mass of soil per m^2 is 1300 kg/m^3 × 0.15 m = 195 kg/ m^2. The mass of soil invertebrates per m^2 is assumed to be 0.04 kg/m^2 (Gonzalez et al. 1999; average reported for *Dacryodes* community). Therefore, the maximum possible BCF_{INV} is 195/0.04 = 4875. The mass-limited maximum possible value is the same for all organic COPCs because it does not depend on deposition rate or K_{ow}, rather soil density and mass density of the receptor. It is mass-limited or deposition-limited because all the mass deposited is accumulated by the receptor. The lesser of the measured or empirically derived BCF_{INV} and the mass-limited BCF_{INV} is used to predict constituent uptake.

Bioconcentration Factors to Mammal and Bird Tissues

The transfer factor to tissues (BCF_A) is the ratio of the COPC or ROPC concentrations in animal tissue to the COPC or ROPC concentration in the material it ingests [(mg/kg_{tissue} wet wt)/ (mg/kg ingested)]. The BCF_A is used to estimate the tissue concentration of animals exposed to COPCs and ROPCs by ingestion of soil, water, and plants from the concentration of COPC or ROPC in the ingested material. The exposure evaluation will consider two versions of BCF_A, measured or empirically derived values and mass-limited values.

Measured or empirically determined values. The measured or empirically determined BCF_A is defined as:

$$BCF_A = \frac{C_A}{C_M} \qquad \text{(SLERAP Eq. 5-2)}$$

where:

BCF_A	=	bioconcentration factor (unitless [soil, sediment], or L/kg [water])
C_A	=	constituent concentration in the terrestrial receptor (animal of interest) (mg/kg or pCi/g)
C_M	=	constituent concentration in media (mg/kg or pCi/g [soil, sediment], or mg/L or pCi/L [water])

Tissue concentrations of COPCs are estimated for animals that are fed upon by wildlife receptors, and tissue concentrations of ROPCs are estimated for all animals.

For medium-to-tissue accumulation factors for mammals and birds, EPA draft guidance (1999) calls for the use of Baes et al. (1984) and Travis and Arms (1988) *Ba* values (d/kg) multiplied by the receptor's absolute ingestion rate for the medium (kg-medium/d). Thus, three *BCF* values are calculated for each COPC and ROPC and each receptor. The *BCF*s are calculated using a modified version of SLERAP equations. The modification is necessary to derive *BCF*s from ingestion rates reported on a body-weight basis:

$$BCF_S = Ba \times IR_F \times SFr \times BW \qquad \text{(modified SLERAP Eq. D-1-1)}$$

$$BCF_P = Ba \times IR_F \times BW \qquad \text{(modified SLERAP Eq. D-1-1)}$$

$$BCF_W = Ba \times IR_w \times BW \qquad \text{(modified SLERAP Eq. D-1-2)}$$

where:

BCF_S	=	soil-to-tissue uptake factor for receptor (kg soil/kg tissue)
BCF_P	=	plant-to-tissue uptake factor for receptor (kg plant/kg tissue)
BCF_W	=	water-to-tissue uptake factor (L water/kg tissue)
Ba	=	ingestion-to-tissue transfer factor (d/kg)
IR_F	=	daily food ingestion rate (kg/kg BW/d)
IR_W	=	daily water ingestion rate (kg/kg BW/d)
SFr	=	soil ingested per unit of food ingested (unitless)
BW	=	body weight of receptor (kg)IR_w = ingestion rate of water by receptor (L/kgBW/d)

Note: The equations above first appear in Section 8.2.3.1.

Ba and *BCF* values are reported in Supplement 4. The first choice for *Ba* values for mammals was EPA draft guidance (1999). *Ba* values for inorganic COPCs and ROPCs that were not included in EPA draft guidance (1999) were taken from Baes et al. (1984), as recommended by EPA (1999). When published field or laboratory values for organic COPCs are not available for mammals, EPA (1999) guidance was followed by using the following regression on K_{ow} (Travis and Arms 1988) for organic compounds (except chlorinated dibenzodioxins and chlorinated dibenzofurans, which use *BEF*s):

$$\log Ba = \log K_{ow} - 7.6 \qquad \text{(SLERAP Eq. D-1-4)}$$

Ba values for dioxins/furans presented by EPA (1999) are *Ba* values presented in EPA (1995a). If neither a *Ba* value nor a K_{ow} is available, no tissue concentration will be calculated.

The first choice for *Ba* values for birds was EPA draft guidance (1999). *Ba* values for inorganic COPCs and ROPCs that were not included in EPA draft guidance (1999) are the same as for mammals. For organic COPCs (except dioxins/furans) the Travis and Arms (1988) *Ba* values for mammals were adjusted for the lower fat content of birds. Per EPA (1999) draft guidance, biotransfer factors for uptake of organic compounds by birds were adjusted for body fat content by multiplying the biotransfer factor by 0.8, which is the assumed ratio of body fat in birds to body fat in mammals.

Mass-Limited Values. It is possible for *Ba* values to predict the accumulation of more mass of a COPC or ROPC than is ingested by the receptor (see Section 7.1.7 for a detailed discussion). The maximum possible uptake factor can be calculated by (1) assuming that all of the COPC or ROPC deposited in a unit area of soil in a specified time period is taken up into the food consumed by animals in that area, (2) assuming that the food is consumed by the receptor at a uniform rate during its lifetime, (3) calculating the ingestion rate of COPC or ROPC by the receptor, and (4) assuming that the receptor accumulates all of the COPC or ROPC during its lifetime. The maximum possible uptake factor is calculated as shown in the following equation:

$$\text{Maximum possible bioconcentration factor} = \frac{\text{COPC or ROPC concentration in receptor tissue (mg/kg)}}{\text{Consumption rate of COPC or ROPC (mg/d)}}$$

Assuming 100 % of the COPC or ROPC in the ingested food is transferred to the animal tissue, the tissue concentration can be calculated as:

$$\text{Concentration in receptor tissue} = \frac{\text{Total COPC or ROPC ingested (mg COPC or ROPC)}}{\text{Tissue weight (kg FW)}}$$

The total COPC or ROPC ingested can be expressed as:

$$\text{Total COPC or ROPC ingested} = \text{Concentration in food (mg/kg)} \times \text{Consumption rate of feed (kg/d)} \times \text{Exposure duration (d)}$$

Combining equations, the general equation for calculating the mass limited food-to-receptor tissue uptake factor can be expressed as:

$$\text{Mass limited uptake factor} = \frac{\text{Concentration in food (mg/kg)} \times \text{Consumption rate of feed (kg/d)} \times \text{Exposure duration (d)}}{\text{Tissue weight (kg FW)} \times \text{Concentration in food (mg/kg)} \times \text{Consumption rate of feed (kg/d)}}$$

This equation can be reduced to:

(Equation 8-21)

$$\text{Maximum possible bioconcentration factor} = \frac{\text{Exposure duration (d)}}{\text{Tissue weight (kg FW)}}$$

The lesser of the measured or empirically derived *Ba* and the mass-limited *Ba* is used to predict constituent uptake. Only receptors with high body weights relative to the lengths of their lives could have mass-limited uptake factors less than the reported or calculated *Ba* values, and in such circumstances, the mass-limited *Ba* value will not be used in lieu of reported or calculated *Ba* values.

FCMs. *FCM*s are factors that are used to quantify bioaccumulation through the food chain. As chemicals from the environment pass up the food chain, they may become successively more concentrated at each trophic level. This is especially true of organic chemicals that are not metabolized rapidly. Typically, organic chemicals that dissolve in lipids bioaccumulate because they are stored in body fat, and the more soluble in lipids the chemical is, the more it bioaccumulates. To model this tendency quantitatively, EPA (1995b) measured bioaccumulation factors for organic chemicals taken up through the food chain from water by fish. An *FCM* was derived for each chemical tested by dividing the observed *BAF* by the K_{ow}. The EPA 1995b was able to show an orderly relationship between *FCM* and K_{ow} for many organic chemicals taken up by fish at trophic levels 2, 3, and 4. By using this relationship, the concentration of a chemical in fish tissue, normalized to lipid content, can be calculated by multiplying the concentration of the chemical dissolved in water by the *BCF* of the chemical and by the chemical's *FCM* (refer to SLERAP Section 5.3.2.3).

The EPA (1995b) has published *FCM*s to describe the ratio of bioaccumulation from animal prey to each of the trophic levels of aquatic predators. The EPA (1999) has adopted the use of *FCM*s to estimate the concentrations of organic COPCs in mammals and birds from ingested animal tissue. The *FCM*s will be used to estimate the bioaccumulation of COPCs by omnivores and of ROPCs by all omnivorous and carnivorous receptors. The *FCM*s will be used to calculate bioaccumulation from animal prey only. Bioaccumulation from ingested plants will be calculated by using a BCF_P.

The concentration of a contaminant in a predator will be calculated as the concentration in the prey multiplied by the predator's *FCM* and divided by the prey's *FCM*. The *FCM*s for organic COPCs are reported in Supplement 4, along with K_{ow} and log K_{ow}. Where K_{ow} values are not available, default values are not used.

All *FCM*s are assumed to equal 1 for both inorganic COPCs and for ROPCs.

8.2.5.4 Bioaccumulation Factors for Calculating Aquatic Exposures

The calculation of exposure for ecological receptors may require one or more bioaccumulation or transfer factors to estimate the concentration in the tissue of an organism from the concentrations in the contaminated media to which it is exposed (Figure 8-13). Such factors are required to estimate exposure for wildlife receptors, such as mammals and birds that are exposed to COPCs and ROPCs in sediment or surface water by ingestion of plants, benthic invertebrates, or aquatic biota, when the concentration in the ingested organism is not measured directly. In each case, the numerator of the factor must have units corresponding to the units of concentration in the medium taking up the substance (tissue), and the denominator must have units corresponding to the units of concentration in the "source" medium (sediment, water, and tissue). The rules for use and derivation of these factors follow.

Water-to-Plant Bioconcentration Factor

The water-to-plant bioconcentration factor (BCF_W) is the ratio of the COPC or ROPC concentration in aquatic plant tissue to that dissolved in water [(mg/kg_{plant} wet wt)/(mg/L)]. The BCF_W will be used to estimate the tissue concentration of aquatic plants exposed to COPCs and ROPCs in surface water from the concentration of COPC or ROPC dissolved in surface water (Figure 8-13). That is:

BCF_W = water-to-plant transfer factor for aquatic plant tissue for COPC or ROPC dissolved in water (L/kg_{plant} wet wt)

Aquatic plants will be assumed to be exposed only to the dissolved phase of contaminants in surface water. Concentrations will be estimated for aquatic plant tissues that are fed upon by terrestrial receptors (e.g., Canada goose).

BCF_W values presented by EPA (1999) are used if they are available. Per EPA draft guidance (1999), values of BCF_W for organic COPCs for which no measured values were available were calculated with an empirically derived equation for uptake from water by aquatic invertebrates (Southworth, Beauchamp, and Schmieder 1978). The equation is:

$$\log BCF_W = 0.819 \times \log K_{ow} - 1.146 \qquad \text{(SLERAP Eq. C-1-4)}$$

Values of BCF_W for inorganic COPCs and ROPCs for which no measured values were available were calculated as the arithmetic mean of all available inorganic *BCF*s. BCF_W values are presented in Supplement 4.

Sediment-to-Plant Bioconcentration Factor

The sediment-to-plant transfer factor (BCF_{sed}) is the ratio of the COPC or ROPC concentration in aquatic plant tissue to that in sediment [(mg/kg$_{\text{tissue}}$ wet wt)/(mg/kg$_{\text{sediment}}$ dry wt)]. The SP will be used to estimate the tissue concentration of aquatic plants exposed to COPCs and ROPCs in sediment (Figure 8-13). That is:

BCF_{sed} = sediment-to-plant transfer factor for aquatic plant tissue (kg$_{\text{sediment}}$ dry wt/kg$_{\text{plant}}$ wet wt)

Per EPA draft guidance (1999), *BCF*s for the uptake from sediment by aquatic plants are assumed to be the same as *BCF* values for uptake from soil by terrestrial plants. The BCF_{sed} values for organic COPCs are taken from EPA (1999). For organic compounds with no field or laboratory data, BCF_{sed} is estimated using the Travis and Arms (1988) regression on K_{ow}:

$$\log BCF_{sed} = 1.588 - (0.578 \times \log K_{ow}) \qquad \text{(SLERAP Eq. C-1-2)}$$

The BCF_{sed} values for inorganic COPCs are taken from EPA draft guidance (1999), Baes et al. (1984), and Cappon (1981) and are provided in Supplement 4. BCF_{sed} values for ROPCs are also taken from Baes et al. (1984) and provided in Supplement 4. Values of BCF_{sed} for inorganic COPCs and ROPCs for which no measured values were available were calculated as the arithmetic mean of all available inorganic BCF_{sed} values.

Water-to-Fish Tissue Bioconcentration Factor

The COPCs and ROPCs are taken up by fish both directly from water and through the food chain. Direct uptake will be calculated by using a *BCF*, and trophic transfer through the food chain will be calculated by using *FCM*s. These factors are discussed below.

Direct Uptake. The water-to-fish tissue transfer factor (*BCF*) is the ratio of the concentration of COPC or ROPC in the tissue of an aquatic receptor to the concentration in water [(mg/kg$_{\text{tissue}}$ wet wt)/(mg/L)]. The fish *BCF* will be used to estimate the tissue concentration of fish from the concentration in the water to which the fish is exposed (Figure 8-13). That is:

BCF_W = water-to-fish tissue transfer factor (L/kg$_{\text{tissue}}$ wet wt)

The fish tissue concentrations are estimated because fish are consumed by wildlife receptors such as herons, bald eagles, and mink.

The first choice for *BCF*s for fish are values reported in EPA draft guidance (1999) or developed using EPA methods (EPA 1999). For organic compounds for which no measured data were available, *BCF*s for fish were calculated using the following regression on the K_{ow} (Bintein et al. 1993):

$$\log BCF_W = 0.91 \times \log K_{ow} - 1.975 \times \log (6.8 \times 10^{-7} \times K_{ow} + 1.0) - 0.786 \qquad \text{(SLERAP Eq. C-1-8)}$$

For inorganic COPCs and ROPCs for which no measured data is available, per EPA draft guidance (1999), the BCF_W was estimated as the arithmetic average of available BCF_{fish} values for other inorganics. BCF_W values are presented in Supplement 4.

FCMs. The EPA (1995b) has published *FCM*s to describe the ratio of bioaccumulation from entry into the food chain to each of four trophic levels of predators. The concentration of a contaminant in an aquatic predator is calculated as the concentration in the prey multiplied by the predator's FCM and divided by the prey's *FCM*. For example, if a heron, which is a carnivore at Trophic Level 4, has a diet of omnivorous fish at Trophic Level 3, the resulting concentration of COPC or ROPC in the heron is calculated as the concentration of COPC or ROPC in the omnivorous fish multiplied by the *FCM* for Level 4 and divided by the *FCM* for Level 3 (Figure 8-13). The *FCM*s for organic COPCs are reported in Supplement 4. All *FCM*s for inorganic COPCs and for ROPCs are assumed to equal 1.

Sediment-to-Benthic Invertebrate Tissue Transfer Factor

The BCF_{INV} is the ratio of the COPC or ROPC concentrations in benthic invertebrate tissue to the COPC or ROPC concentration in bulk sediment [(mg/kg$_{tissue}$ wet wt)/(mg/kg$_{sediment}$ dry wt)]. The BCF_{INV} is used to estimate the tissue concentration of benthic invertebrates exposed to COPCs and ROPCs in sediment by all exposure routes (ingestion, direct contact) from the concentration of COPC or ROPC in bulk sediment (Figure 8-13). The tissue concentration is estimated for animals that are fed upon by wildlife receptors. That is:

BCF_{INV} = sediment-to- benthic invertebrate tissue transfer factor (kg$_{sediment}$ dry wt/kg$_{tissue}$ wet wt)

where the animal is typically a benthic invertebrate, such as a burrowing crustacean or insect, which are important diet items of predators, such as the spotted sandpiper and certain fishes.

The BCF_{INV} values are available in the literature for only a few COPCs and ROPCs. The first choice for BCF_{INV} values is field or laboratory values provided by the EPA (1999). Values of BCF_{INV} values for inorganic COPCs and ROPCs for which no measured values are available are calculated as the arithmetic mean of all available inorganic BCF_{INV} values. BCF_{INV} values are reported in Supplement 4.

For organic COPCs for which no measured data is available, BCF_{INV} values for benthic invertebrates were calculated per EPA (1999) from the octanol water-partitioning coefficient (K_{ow}) using the regression equation for daphnids (Southworth et al. 1978):

$$\log BCF_{INV} = 0.819 \times \log K_{ow} - 1.146 \qquad \text{(SLERAP Eq. C-1-9)}$$

where:

BCF_{INV} = sediment-to-tissue transfer factor for benthic invertebrates (kg$_{sediment}$ dry wt/kg$_{tissue}$ wet wt)

K_{ow} = octanol-water partition coefficient of COPC (L/kg)

For organic COPCs with log K_{ow} values $\geq$2.6, the equilibrium partitioning approach will be used (Section 8.2.3.1). Thus, the calculated BCF_{INV} will be multiplied by the calculated sediment porewater concentration rather than the concentration in sediment to calculate the tissue concentration for the benthic invertebrate.

Surrogate Bioaccumulation Values

Surrogate values for K_{ow} were used to calculate *BCF*s for a number of organic COPCs whose structural and chemical properties are similar to those of the COPCs used as surrogates. The use of surrogates in *BCF* calculations is indicated in Supplement 4.

8.3 Effects Assessment Calculations

The *TRV*s are concentrations or doses of constituents that are associated with a specified level of adverse effect. The *TRV*s (e.g., ecological soil screening level [Eco-SSL] [EPA 2003a], equilibrium partitioning sediment benchmark [ESB], final chronic value [FCV], or secondary chronic value [SCV] [EPA 2003b, 2008]) may be based on a range of concentration or dose benchmarks, including median lethal concentration (LC50), 20 % effect concentration (EC20), LOAEL, or NOAEL. The *TRV*s are used as the denominator in ecological screening quotients (*ESQ*), as shown in the *ESQ* equations (Section 8.4).

8.3.1 Toxicity Reference Values for Terrestrial Receptors

The *TRV*s for receptors dwelling in and, thus, exposed by direct contact with soil (plants, terrestrial invertebrates) are typically values from published sources, if field observations or site-specific toxicity tests of these media are not available. *TRV*s are tabulated in Supplement 4.

8.3.1.1 Single Chemical Toxicity Reference Values for Direct Contact with Soil

The *TRV*s for plants and soil-dwelling invertebrates are derived values associated with some level of inhibition of growth or reproduction based on a review of published single-chemical laboratory studies (e.g., Efroymson et al. 1997a and 1997b).

Terrestrial Plants

Toxicity of COPCs to plants is assumed to be a result of uptake from soil into the plant tissues. Therefore, soil concentrations that are associated with toxicity, usually under experimental conditions, are used as *TRV*s. For terrestrial plant *TRV*s, the hierarchy of choices is as follows:

1 Values from Eco-SSL guidance (EPA 2003a)
2 Values from EPA draft guidance (EPA 1999)
3 Values from MTCA (Ecology 2001)
4 Values from Efroymson et al. (1997a)
5 Values in the ECOTOXicology database (ECOTOX) (EPA 2010)

The COPCs with no *TRV*s will not be evaluated for toxicity, and this lack of data will be handled as an uncertainty. The toxicity equivalence factor approach will be used to assess the impact of exposure to constituents for which toxicity equivalence factors have been established (see Sections 8.3.3 and 8.3.4).

EPA draft guidance (1999) presents 21 published plant *TRV*s and 7 surrogate values. For COPCs that are not included in the EPA draft guidance (1999), *TRV*s were based on a review of published single-chemistry laboratory studies (Efroymson et al. 1997a). Surrogate *TRV*s were used for some

COPCs that lack *TRVs*, as shown in Table 8-3.

These substitutions were made because of similarities in chemical structures and properties between each COPC that was assigned a surrogate and the COPC used as its surrogate. The assignment of surrogate values is subject to change as appropriate data becomes available (i.e., empirical studies are published in the future). The derivation of *TRVs* for terrestrial plants is presented in Supplement 4.

Terrestrial Invertebrates

Toxicity of COPCs to terrestrial invertebrates is assumed to be a result of uptake from soil into the invertebrate's tissues. Therefore, soil concentrations that are associated with toxicity, usually under experimental conditions, are used as *TRVs*. For terrestrial invertebrate *TRVs*, the hierarchy of choices is as follows:

1 Values from Eco-SSL guidance (EPA 2003a)
2 Values from EPA draft guidance (EPA 1999)
3 Values from the MTCA (Ecology 2001)
4 Values from Efroymson et al. (1997b)
5 Values in the ECOTOXicology database (ECOTOX) (EPA 2010)
6 Values in published literature

The COPCs without *TRVs* will not be evaluated for toxicity, and this lack of data will be handled as an uncertainty. The toxicity equivalence factor approach will be used to assess the impact of exposure to constituents for which toxicity equivalence factors have been established (see Sections 8.3.3 and 8.3.4).

The EPA draft guidance (1999) presents 16 published terrestrial invertebrate *TRVs* and 8 surrogate values. For the many COPCs that are not included in the EPA draft guidance (1999) or Washington State Department of Ecology guidance (Ecology 2001), *TRVs* were based on a review of published single-chemistry laboratory studies (Efroymson et al. 1997b). Surrogate *TRVs* were used for some COPCs that lack *TRVs* (Table 8-3).

These substitutions were made because of similarities in chemical structures and properties between each COPC that was assigned a surrogate and the COPC used as its surrogate. The development of *TRVs* for terrestrial invertebrates is presented in Supplement 4.

8.3.1.2 Toxicity Reference Values for Ingestion Exposure of Terrestrial Receptors

For wildlife receptors, ingestion *TRVs* will be used to calculate *ESQs* for the ingestion exposure pathway. For terrestrial mammal and bird *TRVs*, the hierarchy of choices is as follows:

1 Values from Eco-SSL guidance (EPA 2003a)
2 Values from EPA (1999) draft guidance
3 Values from Sample et al. (1996)
4 Values from the ECOTOXicology database (ECOTOX)(EPA 2010)

The COPCs with no *TRV*s will not be evaluated for toxicity, and this lack of data will be handled as an uncertainty. The toxicity equivalence factor approach will be used to assess the impact of exposure to constituents for which toxicity equivalence factors have been established (see Sections 8.3.3 and 8.3.4).

The EPA draft guidance (1999) presents 42 published *TRV*s and 3 surrogate values for mammals and 32 published *TRV*s and 4 surrogate values for birds. For the many COPCs that are not included in the EPA draft guidance (1999), *TRV*s were based on a review of published single-chemistry laboratory studies (Sample et al. 1996).

The outputs from the toxicity studies are subchronic or chronic NOAEL or LOAEL doses (mg/kg BW/d) for the test species. Per EPA draft guidance (1999), if the NOAEL is from a subchronic study, the benchmark is adjusted downward by a factor of 10 to estimate the chronic benchmark. If the benchmark is a LOAEL for a mortality or reproduction endpoint, it is adjusted downward by a factor of 10 to estimate the NOAEL. A subchronic LOAEL is adjusted downward by a factor of 100 to estimate the chronic NOAEL. An uncertainty factor of 100 is applied to acute single-point estimates (e.g., LD50 values) to determine a *TRV*. Surrogate *TRV*s were used for some COPCs that lack *TRV*s (Table 8-3).

These substitutions were made because of similarities in chemical structures and properties between each COPC that was assigned a surrogate and the COPC used as its surrogate. The development of *TRV*s for terrestrial receptors is presented in Supplement 4.

If the desired *TRV* corresponds to the NOAEL, then the endpoint observed in the study should be mortality or reproduction. Nonlethal or nonreproductive NOAELs are conservative (i.e., lower than necessary to protect the receptor), but are used if a NOAEL for mortality or reproduction is not available. If the *TRV* is a LOAEL, then the endpoint observed in the study should be nonlethal or a nonreproductive effect. If the observed LOAEL endpoint is mortality or reproduction, then the nonconservative nature of the *TRV* should be considered in the risk characterization.

8.3.1.3 Toxicity Reference Values for Radiation Exposure of Terrestrial Receptors

Exposure to ionizing radiation (alpha particles, beta particles, and gamma rays) will be evaluated for toxicity to ecological receptors. The risk of cancer as a result of exposure to ionizing radiation is not calculated for ecological receptors because low doses of radiation typically do not induce cancer that would be lethal before the receptors are able to reproduce. Doses that would be associated with cancer risks that would cause marked reductions in populations would be extremely high. Instead, naturally occurring exposures that have been associated with little or no damage to populations are used to derive radiological *TRV*s.

The benchmark values for radiation given by the International Atomic Energy Agency (IAEA) (1992) are 1 mGy/d (0.1 rad/day) for terrestrial mammals and birds, and 10 mGy/d (1 rad/day) for plants, invertebrates, and aquatic biota. These benchmarks are confirmed in *Effects of Ionizing Radiation on Terrestrial Plants and Animals: A Workshop Report* (Barnthouse 1995). Alpha radiation has a much higher effect on biological tissue than beta and gamma radiation because of the large mass of the alpha particle. When internal exposure is being evaluated, it is particularly important to consider the relative effectiveness of the radiation (CCN 063808). To adjust for the greater damage done by alpha particles than by beta and gamma radiation, a *QF* of 10 (Kocher and Trabalka 2000) for alpha radiation was included in the dose calculations to evaluate exposure to ROPCs.

8.3.2 Toxicity Reference Values for Aquatic Receptors

The *TRVs* for receptors dwelling in and, thus, exposed by direct contact to sediment (benthic invertebrates) or surface water (fish, aquatic biota) are typically values from published sources if field observations or site-specific toxicity tests of these media are not available. The units of these values vary by source and medium (e.g., µg/L for surface water and mg/kg dry wt for sediment).

The toxicity equivalence factor approach will be used to assess the impact of exposure to constituents for which toxicity equivalence factors have been established (see Sections 8.3.3 and 8.3.4). In other cases where *TRVs* are not available, surrogate *TRVs* are assigned as shown in Supplement 4 and described below.

8.3.2.1 Single Chemical Toxicity Reference Values for Direct Contact with Water and Sediment

The *TRVs* for aquatic biota and benthic invertebrates are concentrations of COPCs in the medium to which the receptors are exposed.

Aquatic Biota

The *TRVs* for aquatic biota are, in order of preference, FCVs (or SCVs) related to an ESB values (EPA 2003b, 2008), values published in EPA draft guidance (1999) and then other published *TRVs*. The EPA draft guidance (1999) presents 44 published *TRVs* for aquatic biota and 6 surrogate values. The hierarchy of *TRVs* not found in the EPA draft guidance (2003b, 2008, and 1999) is Washington State MTCA values (Ecology 2001), National Ambient Water Quality Criteria (NAWQC) (Suter and Tsao 1996), FCVs (Suter and Tsao 1996), Great Lakes Tier II SCVs (Suter and Tsao 1996), then other toxicity values from recently published aquatic toxicity literature. Surrogate *TRVs* were used for some COPCs that lack *TRVs* (Table 8-3).

These substitutions were made because of similarities in chemical structures and properties between each COPC that was assigned a surrogate and the COPC used as its surrogate. If there is no toxicity value for a COPC, no *TRV* will be listed, and this lack of data will be handled as an uncertainty. The development of *TRVs* for aquatic biota is presented in Supplement 4.

Chinook Salmon and Other Salmonids

Salmonids comprise salmon and trout species. These species have special regulatory, economic, and recreational interest in the Columbia River Basin. Chinook salmon and steelhead trout populations in the Hanford Reach of the Columbia River have been designated ESUs. Salmonids are also of particular cultural importance to the American Indian tribes, whose way of life has inextricably included salmon and trout as food throughout their history. Because of their sensitive status, salmonids will be evaluated separately from other aquatic biota, and more stringent *TRVs* were sought for exposure of salmonids in the Columbia River. Available FCVs (or SCVs) from EPA guidance for derivation of ESBs (EPA 2003b and 2008) were selected as first choice TRV values for PAHs and nonionic organics as the data used for the derivation of these values were subject to a quality review not necessarily performed in the derivation of TRVs in older EPA publications. These values account for the varying biological availability of chemicals in different sediments and allow for the incorporation of the appropriate biological effects concentration (EPA 2003b). The EPA draft guidance (EPA 1999) provides data for aquatic receptors for other constituents, but offers no specific *TRV* data for salmonids. Therefore, when aquatic toxicity values were found that were lower than the *TRVs* listed in EPA draft guidance, they were used as alternative

TRVs for salmonids. Surrogates were made where similarities in chemical structures and properties between each COPC that was assigned a surrogate and the COPC used as its surrogate justified the use (Table 8-3).

Sensitive species chronic values (Suter and Tsao 1996) were used as *TRVs* for salmonids in preference to *TRVs* for aquatic biota, whether or not they came from tests on salmonids. Other published toxicity values for salmonids were also used as *TRVs* for salmonids if they were lower than the *TRVs* for aquatic biota. These data did not necessarily meet criteria for use to calculate NAWQC, but were used as highly conservative screening *TRVs*. Population EC_{20} values (Suter and Tsao 1996) were also used. The population EC_{20} is a value calculated by a computer model using a variety of toxicity data and is intended to be the lowest chronic exposure that would reduce population recruitment by 20 % (Suter and Tsao 1996). Because the calculation produces a range of concentrations for each COPC, the reported 5th percentile lower bound was used as a conservative *TRV*. The derivation of *TRVs* for salmonids is presented in Supplement 4.

Benthic Invertebrates

The *TRVs* for benthic invertebrates are, in order of preference, values from EPA guidance for derivation of ESBs (EPA 2003b and 2008), those published in EPA draft guidance (1999), and then other published *TRVs*. The EPA draft guidance (1999) presents 27 published benthic invertebrate *TRVs* and 19 calculated or surrogate values. The hierarchy of *TRVs* is as follows:

1 Values from EPA guidance for derivation of ESBs (EPA 2003b and 2008)[4]
2 Values from EPA (1999) draft guidance
3 No-effect levels and lowest-effect levels from Persaud et al. (1993)
4 Apparent effects thresholds from Ecology (1994)
5 Values published by Ingersoll et al. (1996)

For COPCs whose values are not available from those sources, values and methods found in Jones, Suter, and Hull (1997) were used. Surrogate *TRVs* were used for some COPCs that lack *TRVs*. In addition to surrogates given in the SLERAP (EPA 1999), surrogates listed in Table 8-3 were used.

These substitutions were made because of similarities in chemical structures and properties between each COPC that was assigned a surrogate and the COPC used as its surrogate. If there is no TRV in these sources, no TRV is listed, and this lack of data will be handled as an uncertainty. The development of *TRVs* for benthic invertebrates is presented in Supplement 4.

8.3.2.2 Toxicity Reference Values for Ingestion Exposure of Predators of Aquatic Biota

The *TRVs* for ingestion exposure of predators of aquatic biota are the same as those for terrestrial mammals and birds (Section 8.3.1.2), with some exceptions[5]. The source of *TRVs* for mammal and bird receptors is presented in Supplement 4.

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[4] ESB values (organic carbon based values) are converted to TRVs for benthic invertebrates by multiplying them by the fraction of organic carbon in the bed sediment ($f_{oc,bs}$).

[5] The exception for use of Eco-SSL values is for the burrowing owl, as the guidance (EPA 2003a, Sect. 1.1) cautions the user that SSL exposure pathways may not be complete for burrowing mammals (i.e., inhalation and dermal exposure pathways may not be negligible for burrowing animals for some chemicals)

8.3.2.3 Toxicity Reference Values for Radiation Exposure of Aquatic Biota

Exposure to ionizing radiation (alpha particles, beta particles, and gamma rays) will be evaluated for toxicity to ecological receptors. The risk of cancer as a result of exposure to ionizing radiation is not calculated for ecological receptors because low doses of radiation typically do not induce cancer that would be lethal before the receptors are able to reproduce. Doses that would be associated with cancer risks that would cause marked reductions in populations would be extremely high. Instead, naturally occurring exposures that have been associated with little or no damage to populations are used to derive radiological *TRVs*.

For all sediment and aquatic biota, the TRV for total (external + internal) whole-body radiological dose from combined external and internal exposure for all ROPCs combined is 1.0 rad/day (IAEA 1992). However, the *TRV* for aquatic wildlife receptors (i.e., birds and mammals) is 0.1 rad/day.

8.3.3 Toxicity Equivalence Factors for Dioxins, Dibenzofurans, and PCBs

Chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls are evaluated as a group because they are thought to act through a common mechanism of toxicity. These chemicals are thought to act by binding to a protein known as the arylhydrocarbon receptor (AR) (see ATSDR 1997 or WHO 1998). The AR-ligand complex is responsible for the activation of genes that have a deleterious effect when they are not under proper regulation by the receptor's hormones. Interaction of dioxins and similar compounds with AR, therefore, can cause immunological, neurological, endocrine, embryotoxic, and other effects.

The similarity in action of these compounds is thought to result from their structural similarity. Dioxin is composed of two benzene rings joined by two carbon-oxygen-carbon bonds on two adjacent carbons of each benzene ring. Dibenzofurans have two benzene rings joined by a carbon-oxygen-carbon bond and a carbon-carbon bond on two adjacent carbons of each benzene ring. Biphenyls consist of two benzene rings joined by a single carbon-carbon bond. To form the polychlorinated derivatives, chloro groups are attached at various locations, as designated in the names of the compounds. Benzene rings are planar (flat) in conformation. Because two adjacent carbons on each benzene ring are joined in dioxins and dibenzofurans, both benzene rings are held in the same plane, and the chloro groups are also in that plane. Therefore, these molecules are said to be coplanar. The coplanar structure appears to be essential for interaction with AR. The benzene rings in biphenyl can rotate relative to each other, unless there are added groups that interfere with rotation (such as 2,2',6,6'-chloro groups, which occupy the carbons immediately on both sides of the carbon-carbon bond joining the rings). The PCB congeners that are able to form a coplanar molecule (and are called *coplanar* PCBs) can interact with AR when they are in that configuration. Therefore, coplanar PCBs are included among the COPCs with similar action to dioxins and dibenzofurans.

The EPA has recommended that TEFs be used to evaluate the cumulative toxicity of chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls. Because these contaminants have a common mechanism of action, it is assumed that their toxicity to biota is additive (WHO 1998, EPA 1999) (i.e., the toxicity of all dioxins, dibenzofurans, and PCBs should be added). Furthermore, their relative potency as chronic toxins is assumed to be related to the degree of affinity for AR, which can be measured much more conveniently than chronic toxic effects. The TEFs have been proposed for several chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls (WHO 1998, EPA 1999), always assigning the toxicity of TCDD, the most potent chlorinated dioxin, a TEF of 1.0. Separate lists were developed for mammals, birds, and fish, and these lists are presented in Supplement 4.

The TEFs are reported in Supplement 4 for individual PCB congeners (such as 2,3,3',4,4',5-hexachloro-biphenyl), but analytical values for individual congeners in the exposure media are sometimes not available. It is also possible to calculate TEFs for Aroclors, which are mixtures of PCB congeners, using the typical composition of Aroclor mixtures.

Using TEFs, *ESQ*s can be calculated for chlorinated dioxins, chlorinated dibenzofurans, and PCBs for which *TRV*s are not available. The *TRV* for 2,3,7,8-TCDD is divided by a COPC's TEF to calculate an equivalent *TRV* of that corresponds to a dioxin or furan without published *TRV* data. The TCDD-equivalent *TRV* of the COPC is then used to calculate the *ESQ* for the COPC. Because the mechanism of action of these compounds is thought to be the same, the TCDD-equivalent *ESQ*s are added to determine the hazard index (*HI*) for the set of dioxins and dibenzofurans.

8.3.4 Toxicity Equivalence Factors for PAHs

As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. They can have a faint, pleasant odor. They are found throughout the environment in the air, water, and soil. They can occur in the air, either attached to dust particles or as solids in soil or sediment. Studies in animals have also shown that PAHs can cause harmful effects on skin, body fluids, and the body's system for fighting disease after both short- and long-term exposure (ATSDR 1995).

EPA 2003b establishes FCVs for PAHs using the NAWQC Guidelines (Stephan et al., 1985). These values serve as TRVs for aquatic biota and fish. The guidance also provides the corresponding ESBs (equivalent concentration in sediments on an organic carbon basis) as predicted from FCVs using the carbon partition coefficient (K_{oc}). These values can be converted to TRVs for benthic invertebrates by multiplying them by the fraction of organic carbon in the bed sediment ($f_{oc,bs}$). The guidance also notes that because PAHs occur in sediments as mixtures and their toxicities in water, tissues, or sediments are additive or nearly additive, their combined toxicities must be considered to assess the impact of PAH mixtures. If the SLERA indicates a potential issue from PAH exposure, the additive effect of the PAH mixture will be assessed as well as their individual impact (see Section 8.4.3).

Additionally, the State of Washington has published TEFs for many of these compounds in MTCA (WAC 173-340-900). These TEFs will be used where appropriate (i.e., for mammals) to calculate equivalent *TRV*s.

8.4 Risk Characterization

Risk estimates for a receptor at an exposure location are calculated as the *ESQ*, which is the ratio of the estimated exposure to the *TRV*. That is:

$$ESQ = \frac{EEL}{TRV} \qquad \text{(SLERAP Eq. 6-1)}$$

where:

ESQ = ecological screening quotient (unitless)

EEL = constituent estimated exposure level (mass of constituent per mass of media [communities] or mass daily dose constituent ingested per mass body weight-day [class-specific guilds])

TRV = toxicity reference value (mass of constituent per mass of media [communities] or mass daily dose ingested per mass body weight-day [class-specific guilds])

The *ESQ* is an index of the total risk to the receptor from exposure to the COPC if the COPC does not occur in the environment from any other source and if the home range of the receptor is smaller than the area of the exposure location, that is, if the $AUF = 1$.

The *ESQ* equation takes different forms depending on how the receptor is exposed, which also determines how the *TRV* is expressed. In the SLERA for the WTP, the exposure to ecological receptors will be a media concentration (EPC), an average daily dose of a COPC (*DD*), or a daily total (external + internal) whole-body radiological dose (DD_{Rad}).

There is limited data for developing inhalation *TRV*s and very limited data for developing dermal *TRV*s. Little is known about the actual absorption across the dermal layer of wildlife receptors. There is also uncertainty about the extrapolation of *TRV*s for ingestion to inhalation. Therefore, inhalation and dermal absorption exposures will not be evaluated quantitatively.

8.4.1 Terrestrial Receptors

For receptors living in soil (such as plants and terrestrial invertebrates), the *ESQ* will be calculated as the ratio of the concentration of COPC in soil and the *TRV* for the receptor and the COPC. That is:

$$ESQ = \frac{Cs_{15}}{TRV} \qquad \text{(modified SLERAP Eq. 6-1)}$$

where:

ESQ = hazard quotient for the receptor at its exposure location for the COPC (unitless)

Cs_{15} = concentration of the COPC in soil at the exposure location based upon a 15 cm root zone soil depth (mg/kg_{soil})

TRV = toxicity reference value of the receptor for the COPC (mg/kg_{soil})

The *ESQ* for a wildlife receptor that does not live in the medium containing COPCs, but is exposed by ingestion and other routes, will be calculated as the ratio of the *DD* and the *TRV*. That is:

$$ESQ = \frac{DD}{TRV} \qquad \text{(modified SLERAP Eq. 6-1)}$$

where:

DD = daily dose of the COPC or ROPC to the receptor at the exposure location (mg/kg BW/d or rad/day) calculated using the concentration of the COPC or ROPC at the exposure location

TRV = toxicity reference value of the COPC or ROPC for the receptor (mg/kg BW/d or rad/day). Note that the ROPC benchmark TRV for terrestrial mammals and birds is 0.1 rad/day and the ROPC benchmark *TRV* for plants and invertebrates is 1.0 rad/day

The second equation will be used to estimate risk for the wildlife receptors in the terrestrial food web: mule deer, mourning dove, Great Basin pocket mouse, western meadowlark, coyote, burrowing owl, and red-tailed hawk.

8.4.2 Aquatic Receptors

For receptors living in surface water or sediment (e.g., aquatic life and salmon and other fish living in surface water, and benthic organisms living in sediment), the *ESQ* will be calculated as the ratio of the measured concentration of COPC in the medium and the *TRV*. That is:

$$ESQ = \frac{C_M}{TRV} \qquad \text{(modified SLERAP Eq. 6-1)}$$

where:

ESQ = hazard quotient for the receptor at its exposure location for the COPC (unitless)

C_M = concentration of the COPC in the exposure media; dissolved surface water, C_{dw} (for fish), or sediment, C_{sed} (for sediment dwellers) at the exposure location (µg/L, mg/L, µg/kg, or mg/kg)

TRV = toxicity reference value of the COPC for the receptor (µg/L, mg/L, µg/kg, or mg/kg)

The *ESQ* for a wildlife receptor that does not live in the surface water or sediment containing the COPCs but is exposed from aquatic food webs by ingestion, inhalation, and other routes is calculated as the ratio of the estimated *DD* (mg/kg BW/d) to the *TRV* (mg/kg BW/d). That is:

$$ESQ = \frac{DD}{TRV} \qquad \text{(modified SLERAP Eq. 6-1)}$$

where:

DD = daily dose of the COPC or ROPC to the receptor at the exposure location (mg/kg BW/d or rad/day) calculated using the concentration of the COPC or ROPC at the exposure location

TRV = toxicity reference value of the COPC or ROPC for the receptor (mg/kg BW/d or rad/day). Note that the ROPC benchmark *TRV* for aquatic mammals and birds is 0.1 rad/day and the ROPC benchmark *TRV* for aquatic biota, salmonids, and benthic invertebrates is 1.0 rad/day

The above equation will be used to estimate risk for the wildlife receptors in the aquatic food web: Canada goose, spotted sandpiper, great blue heron, bald eagle, and mink.

8.4.3 Total Ecological Screening Quotient

The total *ESQ* for a receptor at a given exposure location is the sum of the *ESQ*s for all COPCs with similar modes of toxicity and is an index of the combined risk from exposure to multiple COPCs. A preliminary classification of inorganic COPCs grouped arsenic, antimony, selenium, and vanadium as respiratory inhibitors; lead, manganese, and mercury as central nervous system inhibitors; and aluminum, chromium, and nickel as deoxyribonucleic acid (DNA) and protein reactors. Organic COPCs are typically grouped by chemical structure: volatile organic compounds (VOCs), PAHs, organochloride pesticides, and PCBs. These chemical groupings are based on experience. However, for the SLERA, *ESQ*s for all organic COPCs, all inorganic COPCs, and all ROPCs, regardless of mode of actions, will be grouped and summed because such summing represents the most conservative case. When the total *ESQ* exceeds 0.25, additional *ESQ*s by mode of action will be developed with approval of Ecology if a scientific management decision so indicates. The total *ESQ* for a receptor at an exposure location is calculated from the *ESQ*s for the individual COPCs as follows:

$$ESQ_{Receptor\ COPC\ Total} = \sum ESQ_{COPC\ Specific} \qquad \text{(SLERAP Eq. 6-2)}$$

where:

$ESQ_{Receptor\ COPC\ Total}$	=	total ecological screening quotient for the receptor at the exposure location (unitless)
$ESQ_{COPC\ Specific}$	=	COPC specific ecological screening quotient for the receptor at the exposure location (unitless)

Similarly, the total *ESQ* for a receptor at an exposure location is calculated from the *ESQ*s for the individual ROPCs as follows:

$$ESQ_{Receptor\ ROPC\ Total} = \sum ESQ_{ROPC\ Specific} \qquad \text{(SLERAP Eq. 6-2)}$$

where:

$ESQ_{Receptor\ ROPC\ Total}$	=	total ecological screening quotient for the receptor at the exposure location (unitless)
$ESQ_{ROPC\ Specific}$	=	ROPC specific ecological screening quotient for the receptor at the exposure location (unitless)

The *ESQ* equation for receptors exposed to ROPCs is equivalent to the *ESQ* equation for COPCs because the dose from all radionuclides is summed to estimate the total-body dose from internal and external exposures. Calculating the total *ESQ* assumes an additive effect on receptors from the summed COPCs and ROPCs; however, COPCs and ROPCs effects are not additive with one another, thus, COPCs and ROPCs are evaluated separately.

The threshold value for *ESQ*s for COPCs will be 0.25, unless a similar mode of action is demonstrated and approved by Ecology. The threshold value for *ESQ*s for ROPCs will be 1.0 rad/day for lower trophic level species (plants, aquatic biota, salmonids, and terrestrial and benthic invertebrates) and 0.1 rad/day for higher trophic level species (terrestrial and aquatic mammals and birds).

8.5 Reporting of Major Ecological Risk Findings

Risk characterization will be reported in such a way as to meet three goals identified in EPA guidance (EPA 1999):

1 Provides the maximum, most conservative exposure estimate
2 "Identifies which pathways are driving risk specific to a COPC and receptor"
3 "Allows risk management efforts to be prioritized"

The characterization will interpret risk findings in terms of the receptor groups represented rather than individual receptor species. For example, if there is excess risk to the Great Basin pocket mouse, the result will be interpreted as indicating potential harm to small omnivorous mammals in general.

The following outline of headings is proposed for the PRA:

I. Risk for Terrestrial Conditions: Central Plateau
    A. Organic COPCs
    B. Inorganic COPCs
    C. ROPCs
II. Risk for Aquatic Conditions: Columbia River
    A. Organic COPCs
    B. Inorganic COPCs
    C. ROPCs
III. Future Risk
    A. Terrestrial Conditions
    B. Aquatic Conditions

At each location, every COPC that equals or exceeds an *ESQ* of 0.25 will be identified along with the receptor for which the exceedance occurs. In addition, locations and receptors for which total *ESQ*s equal or exceed 0.25 will be identified, and for each such combination, COPCs and ROPCs whose *ESQ*s exceed 0.025 will be identified as significant contributors to the total *ESQ*. If the results of the SLERA indicate that one or more COPCs or ROPCs or the sum for a receptor at a given exposure location is a potential hazard (i.e., $ESQ \geq 0.25$), then exposure and toxicity information will be re-evaluated to determine whether the evaluation was overly conservative. Evaluation of sources and pathways will help identify which pathways drive the risk. This information will allow risk managers to prioritize further investigation.

Evaluation of *ESQ*s, sources, and pathways will be done for the PRA as well as the FRA within the SLERA.

8.6 Uncertainty in Ecological Risk Assessment

Evaluation of uncertainties is part of the SLERA process (EPA 1998). Uncertainties in each of the four interrelated steps of the EPA approach to the SLERA will be discussed as follows:

- Problem formulation
- Exposure assessment
- Effects assessment
- Risk characterization

Uncertainties about the data will be evaluated in the exposure assessment and the effects assessment steps.

8.6.1 Problem Formulation

Environmental concentrations of contaminants deposited on the soil and water at exposure locations will be based on many predictions. A degree of uncertainty exists about the predicted spatial distribution of contaminants. Exposure concentrations could be overestimated or underestimated, depending on how good the model is at predicting contaminant distribution. The assumption that all soil or surface water in a given exposure area contains the COPC concentrations and ROPC activities modeled for the maximum location results in an overestimate of risk to populations.

Because conservative exposure parameters (Section 8.6.2) will be used to calculate *ESQ*s, the estimates of risk from ecological COPCs and ROPCs are conservative (i.e., protective). Using conservative exposure concentrations decreases the likelihood of underestimating the risk posed by each ecological COPC/ROPC and increases the likelihood of overestimating the risk. Note that for wildlife receptors not living in soil, sediment, or surface water, *ESQ* is a function of COPC dose or radiological daily dose (*DD*), which, in turn, depends on a number of exposure factors (in addition to contaminant exposure concentration). Thus, several factors determine how conservative an *ESQ* might be (in addition to contaminant exposure concentration).

The distribution and abundance of organisms comprising the ecological receptors at exposure locations have not been quantified by field studies. The lack of quantitative data introduces uncertainties concerning whether, and to what extent, the risk characterization based on the selected receptor species underestimates, or overestimates, the risk to organisms that are not used in the risk computations but are found at exposure locations.

One (or more) unobserved species at exposure locations is possibly more sensitive than those ecological species for which toxicity data were available. It does not necessarily follow that these unevaluated species are at significantly greater risk of harmful ecological effects than that estimated in the SLERA, because their exposure may be less than the conservatively estimated exposure for WTP receptors.

8.6.2 Exposure Assessment

Movement of contaminants from the exposure locations through direct and indirect pathways to ecological receptors will be modeled rather than measured for the SLERA. The lack of site-specific measurements introduces uncertainties about the actual modes and pathways of exposure and the actual exposure concentrations of these contaminants to the ecological receptors. Exposure concentrations can differ from the predicted environmental concentrations as a result of physical and chemical processes during transport from source to receptor. These processes will not be predicted quantitatively in the SLERA.

The modes and pathways used to characterize the exposure of ecological receptors are the most important ones for the relatively large and active species in terrestrial habitats. Soil-dwelling terrestrial animals may be exposed to contaminants in soil by way of inhalation. However, it is expected that concentrations of VOCs will be very small and that gaseous concentrations in soil interstices, cavities, and burrows do not exist. Inhalation exposures will not be evaluated in the SLERA. Therefore, the exposure to burrowing organisms at the site from contaminated soil and porewater in the soil may be underestimated if gas concentrations are larger than soil concentrations. Overestimating exposure by using conservative exposure concentrations is thought to offset the underestimation of exposure that results from neglecting certain exposure modes and pathways of lesser importance. Additional uncertainties are inherent in ingestion rates and dietary fractions of plants and animals. Likewise, the effects of dermal exposure may be underestimated; uncertainty about those effects will be discussed qualitatively. Exposure concentrations are likely overestimated because of conservative exposure factors. Sources of conservatism in the exposure factors include using published *BAF*s, irrespective of species and environmental conditions.

8.6.3 Effects Assessment

Toxicity thresholds are based on concentrations reported to have no, or little, effect on the test organism or are estimated conservatively from published toxicity data. The *TRV*s for wildlife receptors exposed to soils are derived from NOAELs or LOAELs reduced by safety factors of 10 for chronic LOAELs and subchronic NOAELs or 100 for subchronic LOAELs (Sample et al. 1996). These thresholds would underestimate the risks only to organisms at the exposure locations that are considerably more sensitive than the receptor organisms for the specific toxicological endpoint. The thresholds are more likely to overestimate the risk to organisms that are equally or less sensitive than the receptor organisms. The possibility remains that some thresholds are set at levels at or above which some harm would occur to organisms at the exposure locations because receptors may be more sensitive to other toxicological endpoints.

There is limited data for developing inhalation *TRV*s and very limited data for developing dermal *TRV*s. Little is known about the actual absorption across the dermal layer of wildlife receptors. There is also uncertainty about the extrapolation of *TRV*s for ingestion to inhalation. Therefore, inhalation exposures will not be evaluated quantitatively. The uncertainties associated with neglecting dermal contact and inhalation toxicity will be discussed in the PRA.

The risks from exposure to multiple contaminants depend on contaminant interactions; effects could be greater or less than those from a single chemical. This RAWP provides methods for estimating ecological COPC-specific risk estimates and assumes additivity for calculating *ESQ*s. Overall, the effects assessment probably overestimates toxicity because the *TRV*s are based on concentrations that cause no observed effect in test animals rather than an effect that may be observable but is not great enough to threaten populations.

*TRV*s are not available for some COPCs. This lack of *TRV*s is especially true for organic COPCs. This situation likely will result in underestimated risks.

The *TRV*s for radiation exposure were proposed as doses that are unlikely to harm populations (IAEA 1992, Barnthouse 1995). Individual plants or animals, or tissues of plants and animals, may be more sensitive to radiation damage than the populations evaluated by IAEA (1992). For example, rapidly growing tissues such as root hairs may be particularly sensitive to external radiation if they are in close contact with contaminated media. Therefore, the SLERA may underestimate risks from radiation by an unknown amount.

Additional uncertainty exists as to the pertinence of individual organism toxicity for characterizing the risk to individuals, populations, and ecosystems. Populations possibly may compensate for the loss of large numbers of juveniles or adults with increased survival or birth rates, and habitats or ecosystems may possess functionally redundant species that are less sensitive to contaminants. Although the desert habitat at the exposure locations likely possesses some buffering mechanisms, a conservative risk assessment approach is still justified based on organismal toxicity thresholds (i.e., NOAELs), which probably result in an overestimate of risk.

8.6.4 Risk Characterization

The uncertainties described above ultimately produce uncertainty in the quantification of current and future risks to plants and animals at the exposure locations. An additional area of uncertainty in the risk characterization is risk to receptors outside of the exposure areas to be modeled.

It is unlikely that receptors outside the areas of maximum concentration and within the 50 km study area would have lower toxicity thresholds for contaminants than the thresholds used for receptors within those exposure areas. All representative organisms are assumed to be present at the locations of maximum concentration regardless of their actual distribution. In addition, there is little reason to expect that contaminants migrating outside the study area would be concentrated above the concentrations predicted at the exposure locations. In general, the risk to receptors outside the exposure areas is likely to be overestimated rather than underestimated (e.g., bounded) by the risk estimate for receptors at the modeled exposure areas within the 50 km radius of the site.

8.6.5 Summary of Uncertainties

The most important uncertainties in the ecological portion of the SLERA for exposure locations are those surrounding the estimates of the contaminant concentrations to which ecological receptors are actually exposed (EPCs) and the concentrations that present an acceptable level of risk or harmful effects (toxicity thresholds or reference values). These uncertainties arise from multiple sources (e.g., the lack of site-specific data on contaminant transport and transformation processes, organismal toxicity, animal behavior and diet, population dynamics, and the response of arid land plant and animal populations to stressors in their environments). Despite these uncertainties, the modeled exposure concentrations and published exposure and effects information will allow risks to be characterized for various exposure locations according to exposure/effects scenarios.

8.7 Summary for Screening-Level Ecological Risk Assessment

Risks to ecological receptors from the potential emission of COPCs and ROPCs result from exposure to and ecological toxicity of the COPCs and ROPCs. The SLERA will utilize the estimated emission rates (Section 5) and results of fate and transport modeling (Section 6) to calculate potential ecological receptor exposure to COPCs and ROPCs. This exposure information is combined with toxicity data to estimate the potential for adverse effects to terrestrial and aquatic organisms and populations in the vicinity of the WTP.

The SLERA will use conservative exposure assumptions to compensate for the high level of uncertainty associated with conducting a risk assessment for a facility that is still in the final design phases. The PRA will include a qualitative uncertainty analysis. The exact procedures that may be used to identify and evaluate the primary sources of uncertainty in the FRA will be determined at a later time.

The FRA will include estimated emissions based on engineering calculations (e.g., PT system emissions and vapor-phase organic emissions from WTP process cells) and environmental performance demonstration tests for the LAW and HLW vitrification systems. Based on the results of the environmental performance demonstration tests, the FRA may involve running new models, modeling additional chemicals, or changing model parameters. Information that will require updating in the FRA, as specified in the WTP DWP (WA7890008967), includes:

- Toxicity data current at the time of the submittal
- Compounds newly identified, or updated emissions data from current waste characterization and emission testing
- Air modeling updated to include stack gas parameters based on most current emissions testing and current WTP unit design
- Physical/transport properties of constituents current at the time of the submittal
- Process description based on current WTP unit design
- Emissions data and all supporting calculations based on current WTP unit design
- Update of receptor locations based on land use or land use zoning, changes, if any

If the risk goals are exceeded in the PRA or the FRA, additional site-specific data will be evaluated for use in the assessments, subject to Ecology approval.

8.8 References

8.8.1 Project Documents

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Table 8-1 Threatened and Endangered Species at Hanford

Common Name	Scientific Name	Habitat	Federal Status [(a)]	State Status [(a)]
Plants				
Awned Halfchaff Sedge	*Lipocarpha (= Hemicarpha) aristulata*	Riparian	-	Threatened
Beaked Spike-Rush	*Eleocharis rostellata*	Priest Rapids	-	Sensitive
Canadian St. John's Wort	*Hypericum majus*	Riparian	-	Sensitive
Chaffweed	*Anagallis (=Centunculus) minimus*	Riparian Wetlands	-	Threatened
Columbia Milkvetch	*Astragalus columbianus*	Umtanum Ridge Shrub-steppe	Species of concern	Sensitive
Columbia Yellowcress	*Rorippa columbiae*	Riparian	Species of concern	Endangered
Coyote Tobacco	*Nicotiana attenuata*	Cold Creek Valley	-	Sensitive
Desert Cryptantha	*Cryptantha scoparia*	ALE Reserve	-	Sensitive
Desert Dodder	*Cuscuta denticulata*	Whaluke Slope	-	Threatened
Desert Evening Primrose	*Oenothera caespitosa*	Cobbled soil near Columbia River (China Bar)	-	Sensitive
Dwarf Evening Primrose	*Camissonia (= Oenothera) pygmaea*	Shrub-steppe	-	Sensitive
Fuzzytongue Penstemon	*Penstemon eriantherus whitedii*	White Bluffs	-	Sensitive
Geyer's Milkvetch	*Astragalus geyeri*	Whaluke Slope	-	Threatened
Grand Redstem	*Ammannia robusta*	Riparian	-	Threatened
Gray Cryptantha	*Cryptantha leucophaea*	Sand dunes Shrub-steppe	Species of concern	Sensitive
Great Basin Gilia	*Aliciella (=Gilia) leptomeria*	Gable Mountain Whaluke Slope	-	Threatened
Hoover's Desert Parsley	*Lomatium tuberosum*	Umtanum Ridge Basalt outcrops	Species of concern	Sensitive
Loeflingia	*Loeflingia squarrosa var. squarrosa*	Gable Mountain	-	Threatened
Lowland Toothcup	*Rotala ramosior*	Riparian	-	Threatened
Piper's Daisy	*Erigeron piperianus*	Shrub-steppe	-	Sensitive
Rosy Pussypaws	*Calyptridium roseum*	Gable Mountain	-	Threatened

Table 8-1 Threatened and Endangered Species at Hanford

Common Name	Scientific Name	Habitat	Federal Status [(a)]	State Status [(a)]
Small-Flowered Evening-Primrose	*Camissonia (= Oenothera) minor*	FEALE Reserve Gable Mountain 200 Area (gravel pit)	-	Sensitive
Snake River Cryptantha	*Cryptantha spiculifera (= C. interrupta)*	White Bluffs	-	Sensitive
Suksdorf's Monkey Flower	*Mimulus suksdorfii*	Gable Mountain Gable Butte Vernita grade	-	Sensitive
Umtanum Desert Buckwheat	*Eriogonum codium*	Umtanum Ridge	Candidate	Endangered
White Bluffs Bladderpod	*Lesquerella tuplashensis*	White Bluffs	Candidate	Threatened
White Eatonella	*Eatonella nivea*	Whaluke Slope	-	Threatened
Mollusks				
California Floater	*Anodonta californiensis*	River and streams - Slow current	Species of concern	Candidate
Great Columbia River Spire Snail	*Fluminicola columbiana*	Hanford Reach	Species of concern	Candidate
Shortfaced Lanx	*Fisherola nuttalli*	Hanford Reach	-	Candidate
Insects				
Columbia River Tiger Beetle [(b)]	*Cicindela columbica*	see footnote [(b)]	-	Candidate
Silver-Bordered Fritillary	*Boloria selene atrocostalis*	Riparian	-	Candidate
Fish				
Bull Trout [(c)]	*Salvelinus confluentus*	Hanford Reach	Threatened	Candidate
Leopard Dace [(c)]	*Rhinichthys flacatus*	Hanford Reach	-	Candidate
Mountain Sucker [(c)]	*Catastomus platyrhynchus*	Hanford Reach	-	Candidate
Pacific lamprey	*Lampetra tridentata*	Hanford Reach	Species of concern	-
River Lamprey [(c)]	*Lampetra ayresi*	Hanford Reach	Species of concern	Candidate
Spring-Run Chinook Salmon	*Oncorhynchus tshawytscha*	Hanford Reach	Endangered	Candidate
Steelhead	*Oncorhynchus mykiss*	Hanford Reach	Threatened	Candidate
Amphibians and Reptiles				
Sagebrush Lizard	*Sceloporus graciosus*	Shrub-steppe (low elevations and sandy areas)	Species of concern	Candidate

Table 8-1 Threatened and Endangered Species at Hanford

Common Name	Scientific Name	Habitat	Federal Status [(a)]	State Status [(a)]
Striped Whipsnake	*Masticophis taeniatus*	Shrub-steppe	-	Candidate
Western Toad	*Bufo boreas*	Riparian	Species of concern	Candidate
Birds				
American White Pelican	*Pelecanus erythrorhynchos*	Riparian	-	Endangered
Bald Eagle [(d)]	*Haliaeetus leucocephalus*	Riparian	Species of concern	Sensitive
Burrowing Owl	*Athene cunicularia*	Shrub-steppe	Species of concern	Candidate
Common Loon	*Gavia immer*	Riparian	-	Sensitive
Ferruginous Hawk	*Buteo regalis*	Transmission line towers Shrub-steppe	Species of concern	Threatened
Flamulated Owl [(c)]	*Otus flammeolus*	Shrub-steppe	-	Candidate
Golden Eagle	*Aquila chrysaetos*	Shrub-steppe	-	Candidate
Greater Sage Grouse	*Centrocercus urophasianus*	Shrub-steppe	Candidate	Threatened
Lewis's Woodpecker [(c)]	*Melanerpes lewisi*	Riparian Shrub-steppe	-	Candidate
Loggerhead Shrike	*Lanius ludovicianus*	Shrub-steppe	Species of concern	Candidate
Merlin	*Falco columbarius*	Riparian Shrub-steppe	-	Candidate
Northern Goshawk [(c)]	*Accipter gentilis*	Shrub-steppe	Species of concern	Candidate
Olive-Sided Flycatcher	*Contopus cooperi*	Riparian	Species of concern	-
Peregrine Falcon	*Falco peregrinus*	Riparian Shrub-steppe	Species of concern	Sensitive
Sage Sparrow	*Amphispiza belli*	Shrub-steppe	-	Candidate
Sage Thrasher	*Oreoscoptes montanus*	Shrub-steppe	-	Candidate
Sandhill Crane	*Grus canadensis*	Islands Riparian Shrub-steppe	-	Endangered
Western Grebe	*Aechmorus occidentalis*	Riparian	-	Candidate
Mammals				
Black-Tailed Jackrabbit	*Lepus californicus*	Shrub-steppe	-	Candidate

Table 8-1 Threatened and Endangered Species at Hanford

Common Name	Scientific Name	Habitat	Federal Status [(a)]	State Status [(a)]
Merriam's Shrew	*Sorex merriami*	Shrub-steppe	-	Candidate
Townsend's Ground Squirrel	*Spermophilus townsendii*	Benton County Shrub-steppe	Species of concern	Candidate
Washington Ground Squirrel [(c)]	*Spermophilus washingtoni*	Shrub-steppe	Candidate	Candidate
White-Tailed Jackrabbit	*Lepus townsendii*	Shrub-steppe	-	Candidate

(a) "-" indicates species is not listed a endangered, threatened, candidate, sensitive, or of concern.

Endangered = Species in danger of extinction within all or a significant portion of its range.

Threatened = Species likely to become endangered in the foreseeable future.

Candidate = Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.

Sensitive = Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats.

Species of concern = Species that are not currently listed or candidates under the Endangered Species Act, but are of conservation concern within specific US Fish and Wildlife Service regions.

(b) Probable, but not observed, on the Hanford Site.

(c) Reported, but seldom observed, on the Hanford Site.

(d) Reclassified January 2008.

Refs: PNNL. 2010. *Hanford Site Environmental Report for Calendar Year 2009*, PNNL-19455, September 2010. Pacific Northwest National Laboratory, Richland, Washington.

PNNL. 2001. *Vascular Plants of the Hanford Site*. PNNL-13688. Pacific Northwest National Laboratory, Richland, Washington.

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Table 8-2 Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Area and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
Policy Goal 1: The conservation of threatened and endangered species and their critical habitats.	**Assessment Endpoint 1:** Protection of individuals of state or federally designated threatened or endangered (T&E) species. Endpoint species: redtailed hawk.	**Measure 1:** Modeled contaminant concentrations in prey (such as, deer mouse, western meadowlark, Great Basin pocket mouse, mourning dove, and fish) based on modeled concentrations of vapors in air and particulates, depositions of contaminant particulates to soil and surface water, and measured concentrations of contaminants in abiotic media. These concentrations are used to evaluate exposure of threatened and endangered predators. Chronic exposure concentrations and doses associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 1:** If threatened or endangered species are not present, or exposure point concentrations in the media do not contribute to the chronic NOAEL, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, the threatened or endangered species should be preserved. If the HQ $\geq$0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 2: The protection of terrestrial populations and ecosystems.	**Assessment Endpoint 2:** Stable plant community for erosion control and energy production. Endpoint species: cheatgrass, rabbitbrush.	**Measure 2**: Modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil. Chronic exposure concentrations associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 2:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, the plant populations and communities are maintained. If the HQ $\geq$0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 2: The protection of terrestrial populations and ecosystems.	**Assessment Endpoint 3:** Stable soil-dwelling invertebrate community for nutrient and energy processing. Endpoint species: earthworms and darkling beetles.	**Measure 3:** Modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil. Chronic exposure concentrations associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 3:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, the terrestrial invertebrate community is maintained. If the HQ $\geq$0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 8-2 Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Area and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
	Assessment Endpoint 4: Stable populations of herbivorous animals. Endpoint species: mammals - mule deer; birds - mourning dove.	**Measure 4:** Modeled contaminant concentrations in food chain (such as, plants) based on modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil. Chronic exposure doses associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 4:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of the herbivores (such as, mule deer and mourning dove) are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 5: Stable populations of animals that eat both plants and animals (omnivores). Endpoint species: bird - western meadowlark.	**Measure 5:** Modeled contaminant concentrations in earthworms, plants, and other prey based on modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil. Chronic exposure doses associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 5:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of omnivores (such as, western meadowlark) are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 2: The protection of terrestrial populations and ecosystems.	**Assessment Endpoint 6:** Stable populations of terrestrial predators. Endpoint species: mammal - coyote; bird - burrowing owl and red-tailed hawk.	**Measure 6:** Modeled contaminant concentrations in prey (such as, western meadowlark and Great Basin pocket mouse) based on modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil. These concentrations are used to evaluate exposure of predators. Chronic exposure doses associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 6:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of terrestrial predators are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 8-2 Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Area and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
Policy Goal 3: The protection of aquatic populations and ecosystems.	**Assessment Endpoint 7:** Stable populations of sediment-dwelling organisms. Endpoint species: clams, insects, snails, and worms.	**Measure 7:** Modeled sediment contaminant concentrations from dispersion and deposition. Chronic exposure concentrations associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 7:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of sediment-dwelling organisms are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 8: Stable populations of planktivorous fish and small invertebrates. Endpoint species: water fleas and other invertebrates.	**Measure 8:** Modeled surface water contaminant concentrations. Chronic exposure concentrations associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 8:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of small invertebrates are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 3: The protection of aquatic populations and ecosystems.	**Assessment Endpoint 9:** Stable waterfowl and shorebird populations. Endpoint species: Canada goose, spotted sandpiper.	**Measure 9:** Modeled contaminant concentrations in benthic invertebrates or aquatic plants based on modeled contaminant concentrations in surface water or sediments from dispersion and deposition. These concentrations are used to evaluate exposure of predators. Chronic exposure doses associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 9:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of waterfowl and shorebirds are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 10: Stable populations of large carnivorous fish population for regulation. Endpoint species: salmon, bass, channel catfish.	**Measure 10:** Modeled surface water and sediment contaminant concentrations. Chronic exposure concentrations associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 10:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of large carnivorous fish are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 8-2 Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Area and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
	Assessment Endpoint 11: Stable fish-eating terrestrial predator populations for population regulation. Endpoint species: mammal - mink; birds - great blue heron, bald eagle.	**Measure 11:** Modeled contaminant concentrations in large carnivorous fish and planktivorous fish and small invertebrates based on modeled surface water and sediment concentrations. These concentrations are used to evaluate exposure of predators. Chronic exposure doses associated with no adverse effect on survival and reproduction.	**Decision Rule for Assessment Endpoint 11:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of fish-eating terrestrial predators are maintained. If the HQ ≥0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

T&E = Threatened and endangered.

NOAEL = No observed adverse effects level.

HQ = Hazard quotient.

Table 8-3 Ecological Assessment TRV Surrogates

Constituent	Surrogate
5-nitroacenaphthene (CAS #602-87-9)	acenaphthene (CAS #83-32-9)
methyl isocyanate (CAS #624-83-9)	acrylonitrile (CAS #107-13-1)
trichlorofluoroethane (CAS #27154-33-2)	trichlorofluoromethane (CAS #75-69-4)
2,4-toluene diisocyanate (CAS #584-84-9)	2,4-dinitrotoluene (CAS #121-14-2)
hydrogen chloride (CAS #7647-01-0)	chlorine (CAS #7782-50-5)

Figure 8-1 Ecological Resources Conceptual Exposure Model

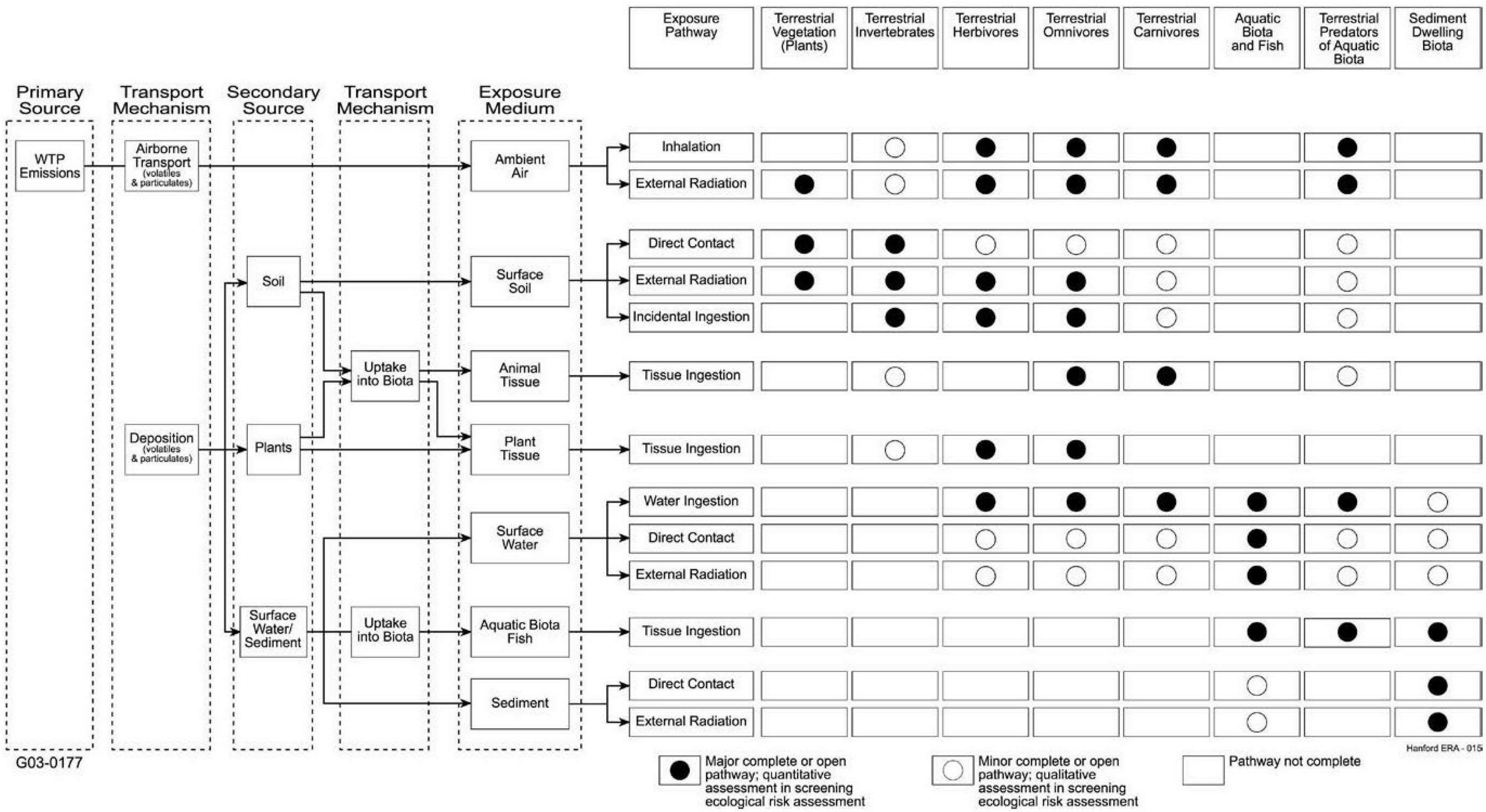


Figure 8-2 Recreation and Wildlife Areas and the Hanford Reach

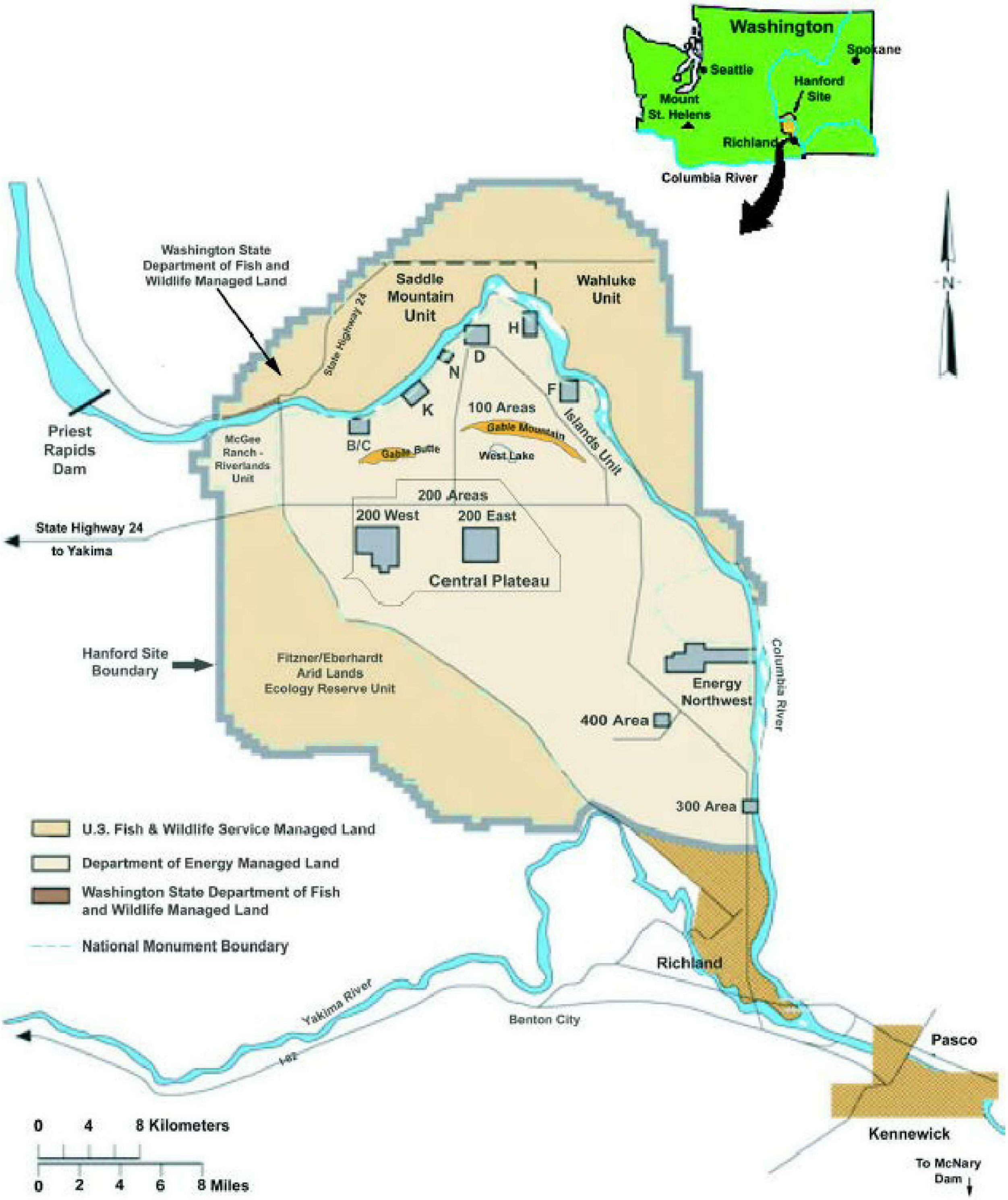
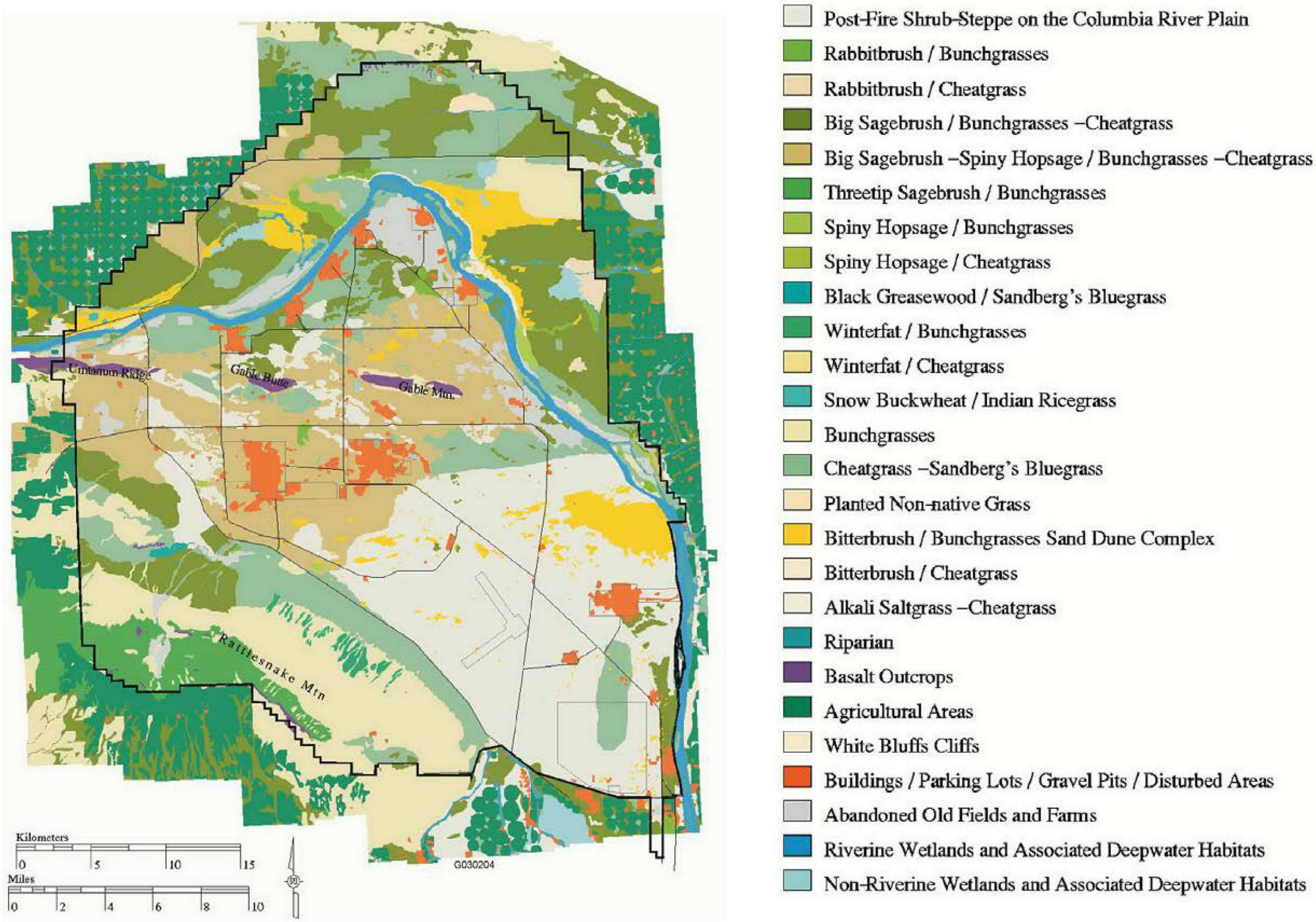


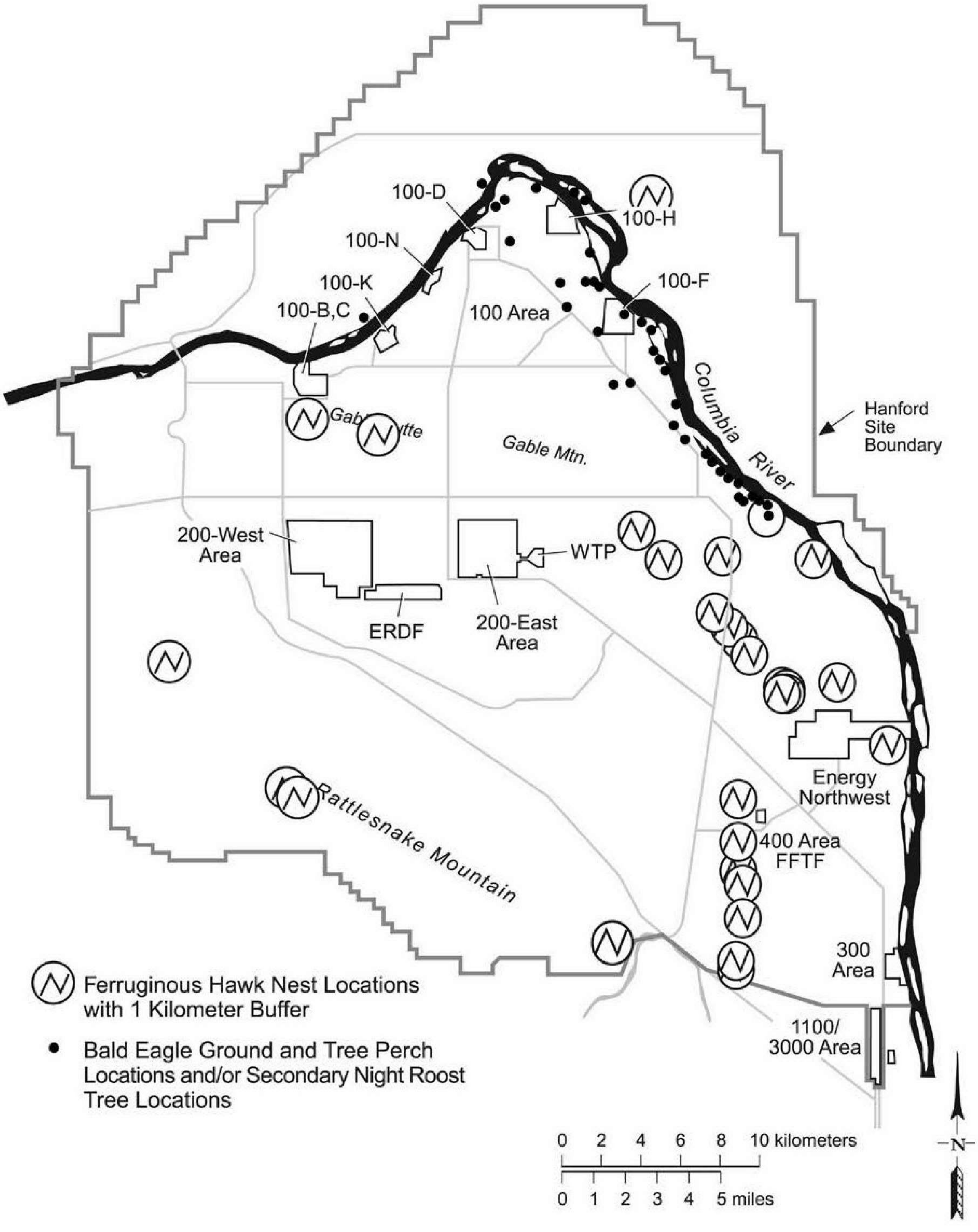
Figure 8-3 Regional Geography, Water Bodies, Roads, and Communities

Figure 8-4 Vegetation Types of the Hanford Site



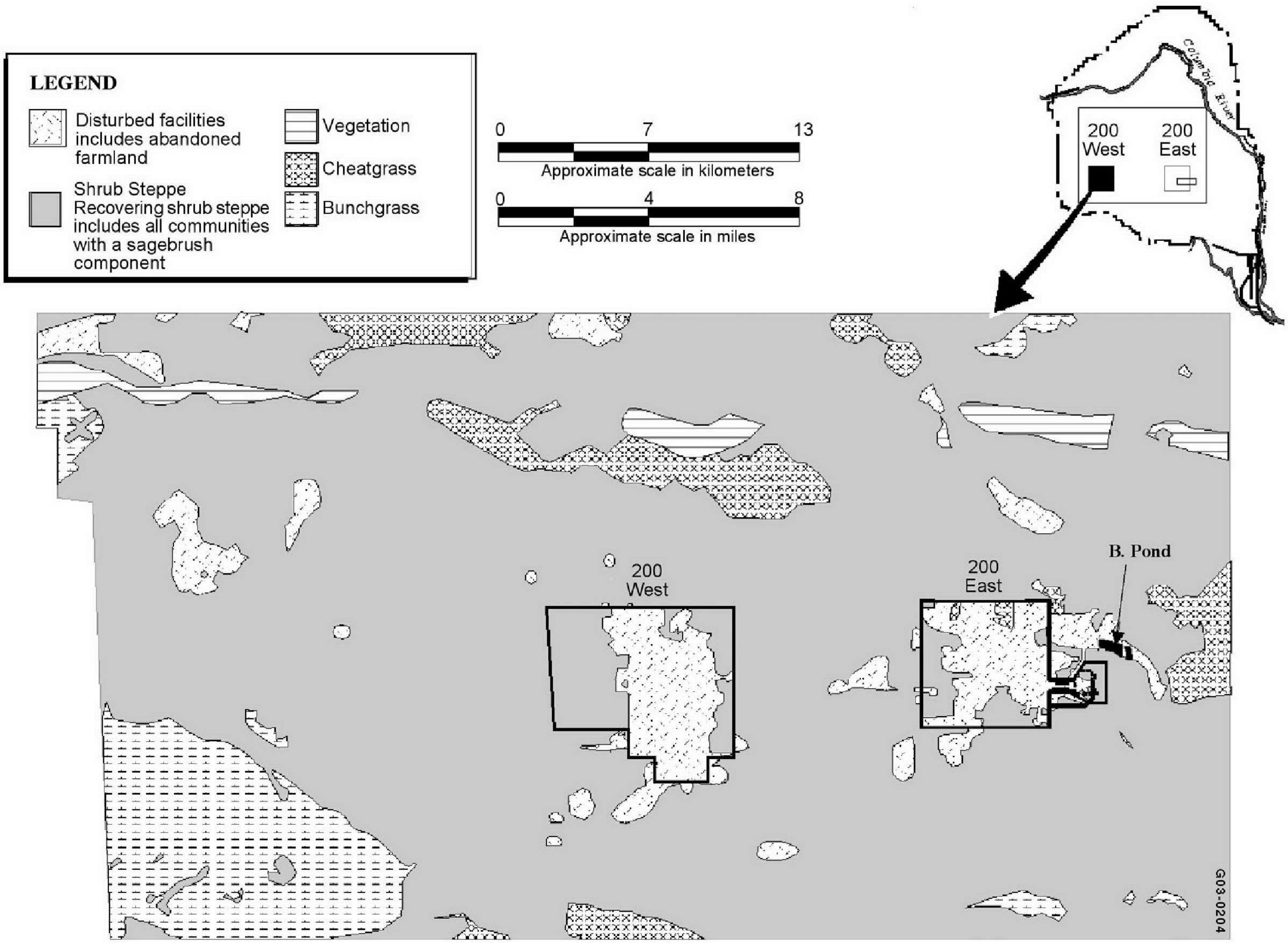
BHI:rpp 04/22/96 clup/brmap d02.aml Database: 07-DEC-1998

1 **Figure 8-5 Selected Raptor Nesting and Perching Locations on the Hanford Site**



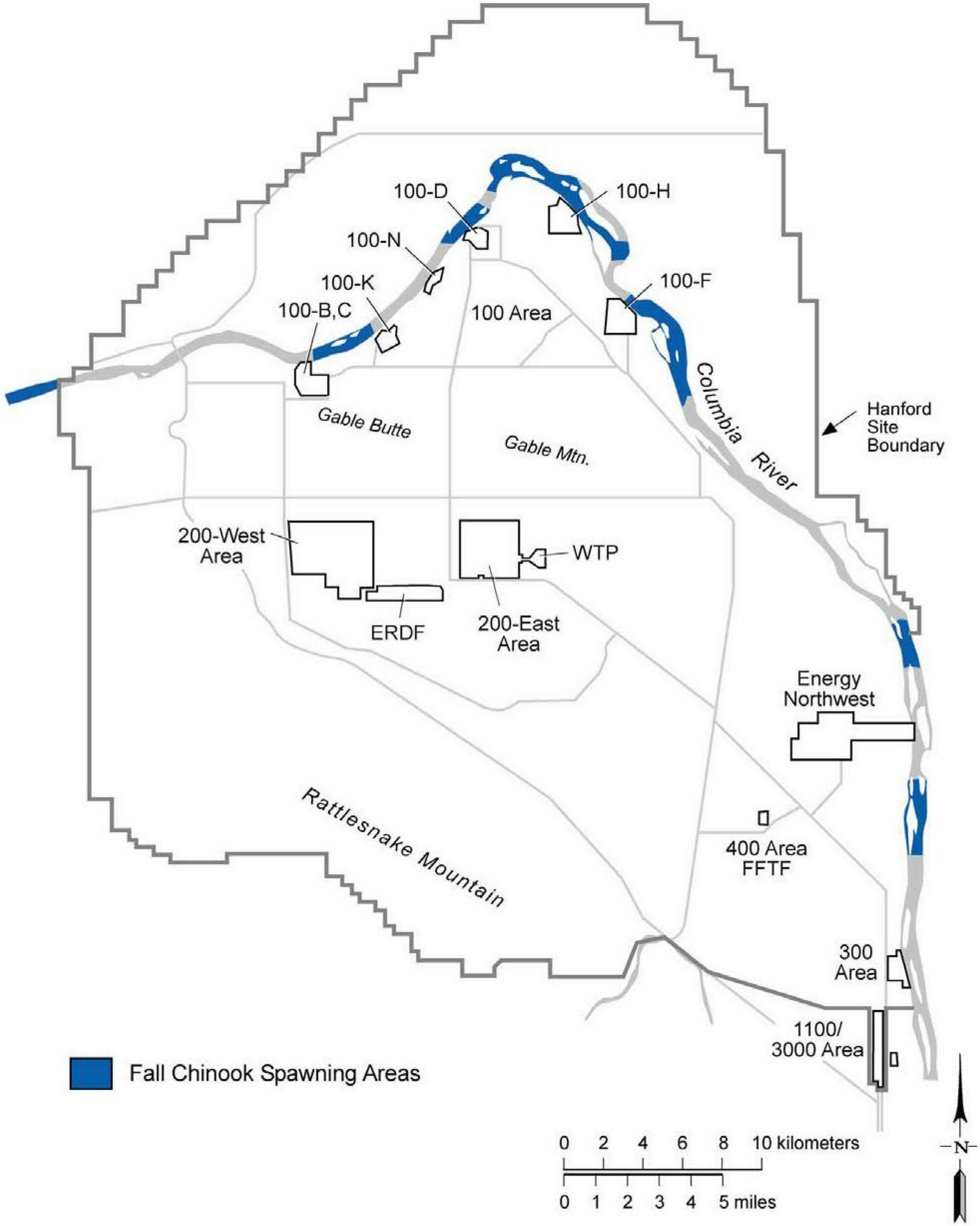
2
3

1 **Figure 8-6 WTP Areas Vegetation Types (Simplified)**



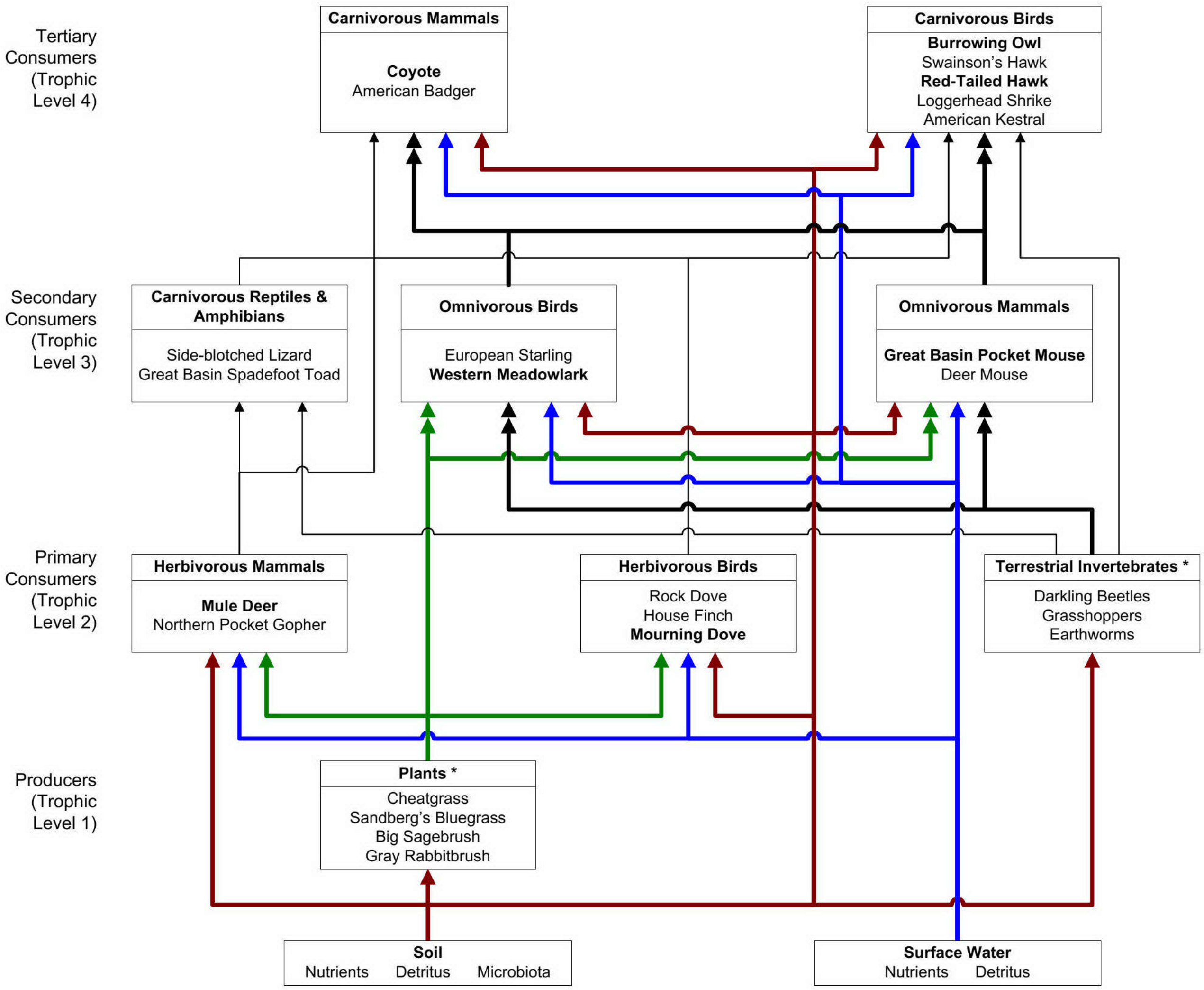
2

1 **Figure 8-7 Fall Chinook Salmon Spawning Areas Along the Columbia River**



2

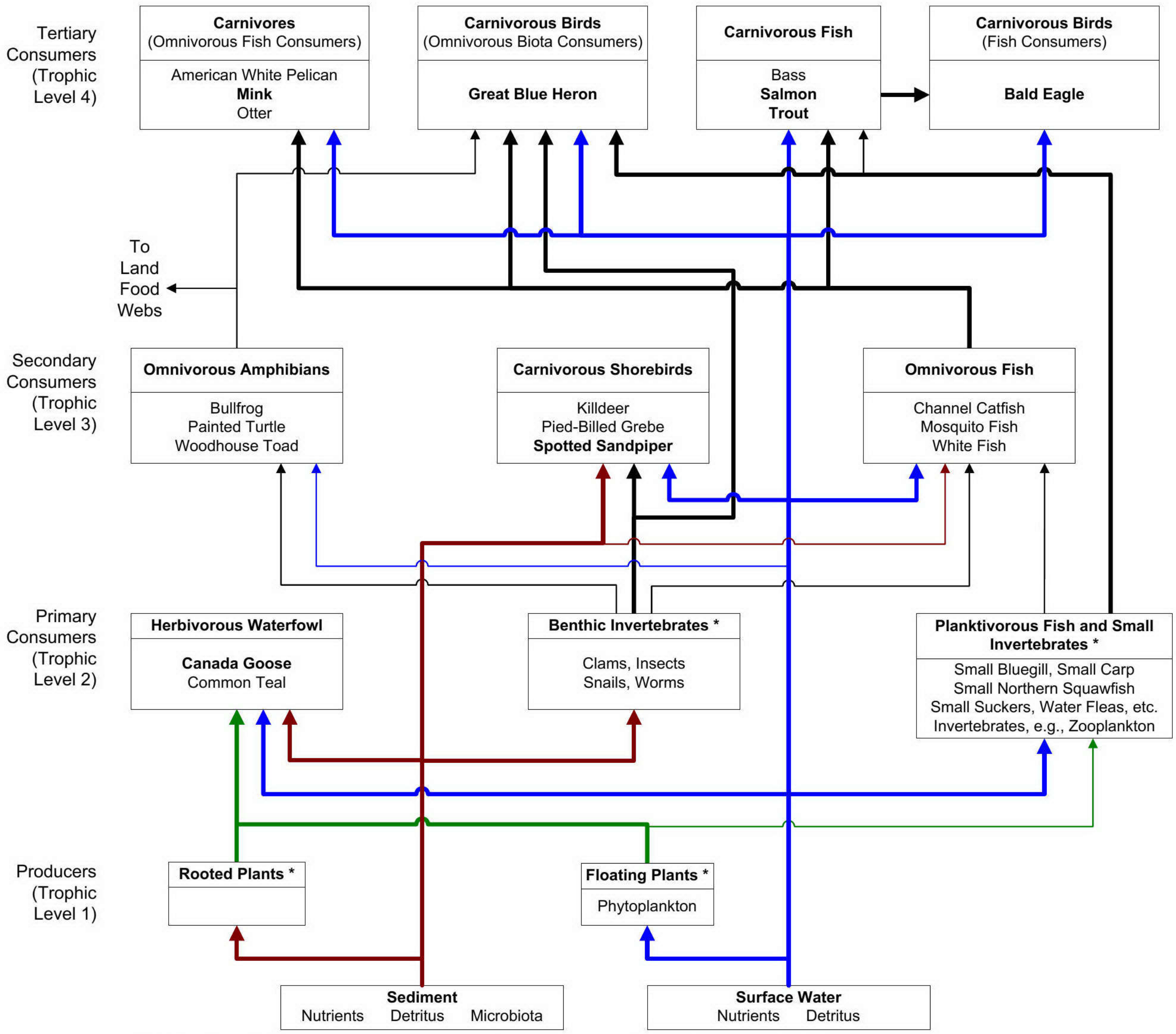
Figure 8-8 Trophic Levels and Measurement Receptor Species Evaluated in the Hanford Site and Vicinity Terrestrial Conceptual Exposure Model



Bold-faced type indicates measurement receptors for which exposure will be evaluated quantitatively.
Heavy lines indicate exposure pathways that will be evaluated quantitatively.
Thin lines indicate exposure pathways that will not be evaluated quantitatively.
Double arrow heads indicate food source is one of two potential exclusive food sources (see Section 8.2.1).
Line color indicates ingestion pathway (brown=soil, blue=water, green=plant, black=prey).

* Species specific measurement receptors not identified because the group is evaluated on a community level.

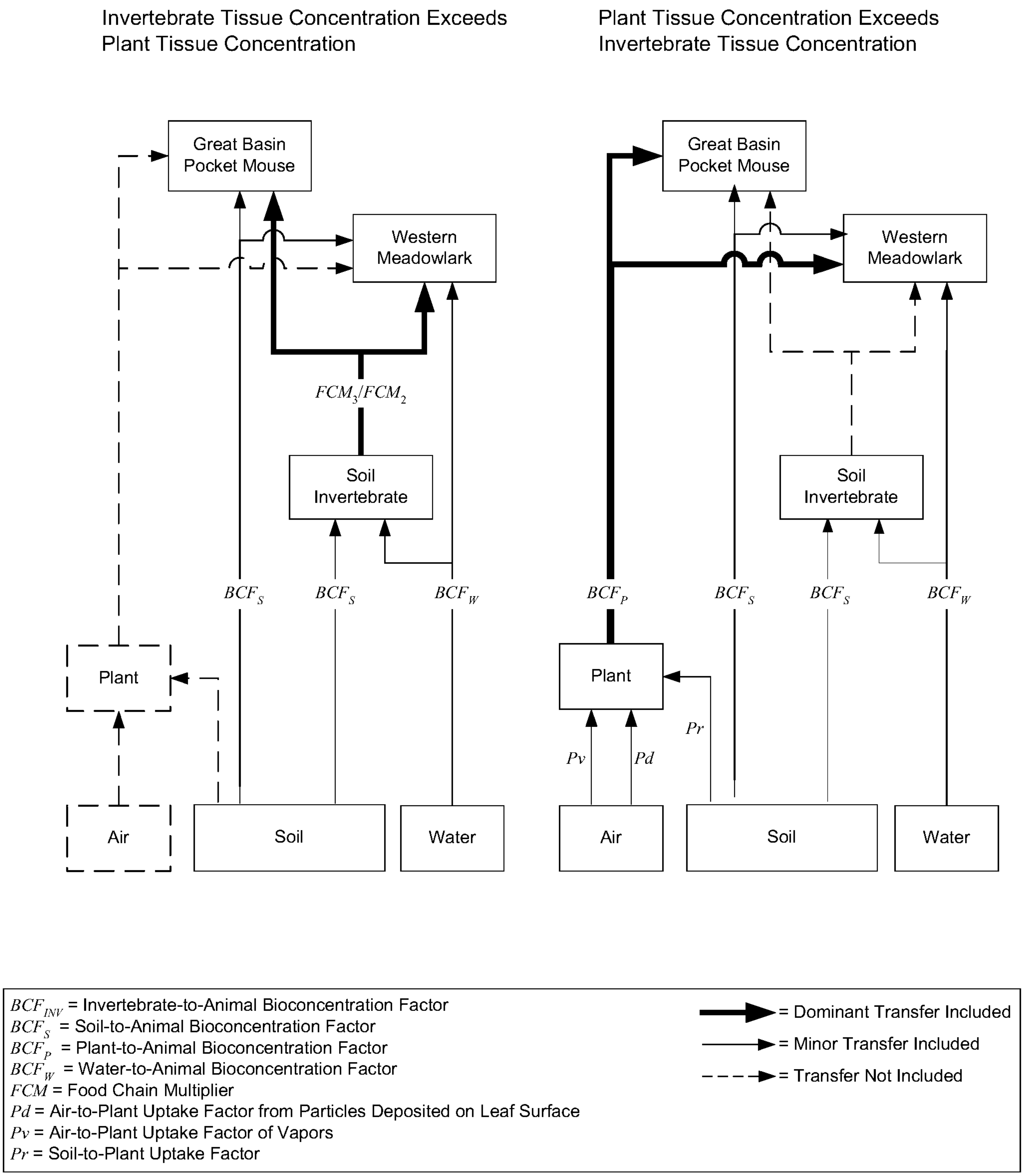
Figure 8-9 Trophic Levels and Measurement Receptor Species Evaluated in the Columbia River Aquatic Conceptual Exposure Model



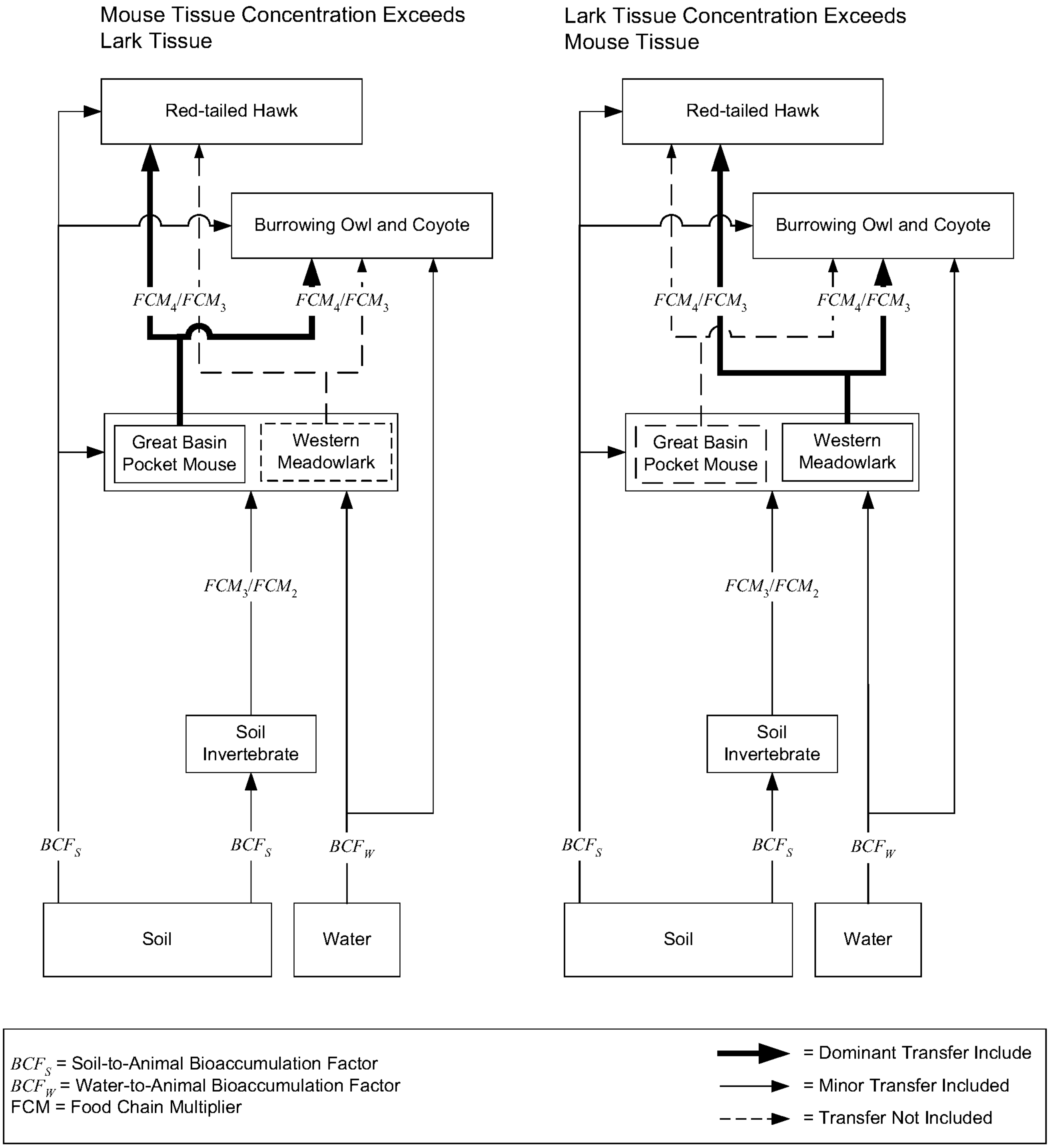
Bold-faced type indicates measurement receptors for which exposure will be evaluated quantitatively.
Heavy lines indicate exposure pathways that will be evaluated quantitatively.
Thin lines indicate exposure pathways that will not be evaluated quantitatively.
Line color indicates ingestion pathway (brown=soil, blue=water, green=plant, black=prey).

* Species specific measurement receptors not identified because the group is evaluated on a community level.

Figure 8-10 Exclusive Diets for Omnivores



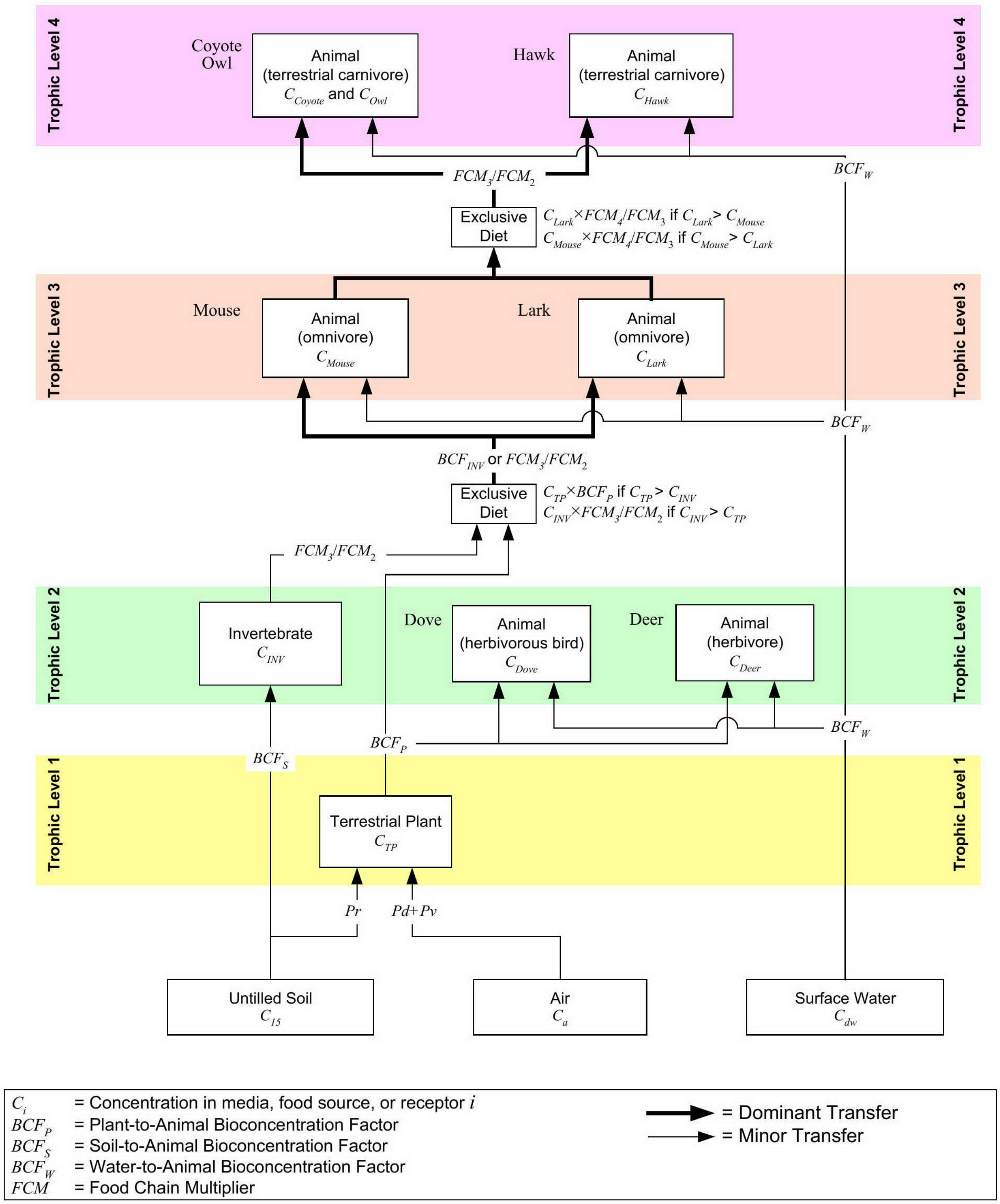
1 **Figure 8-11 Exclusive Diets for Carnivores**



2 * FCMs for Top Predators Are Used for ROPCs Only

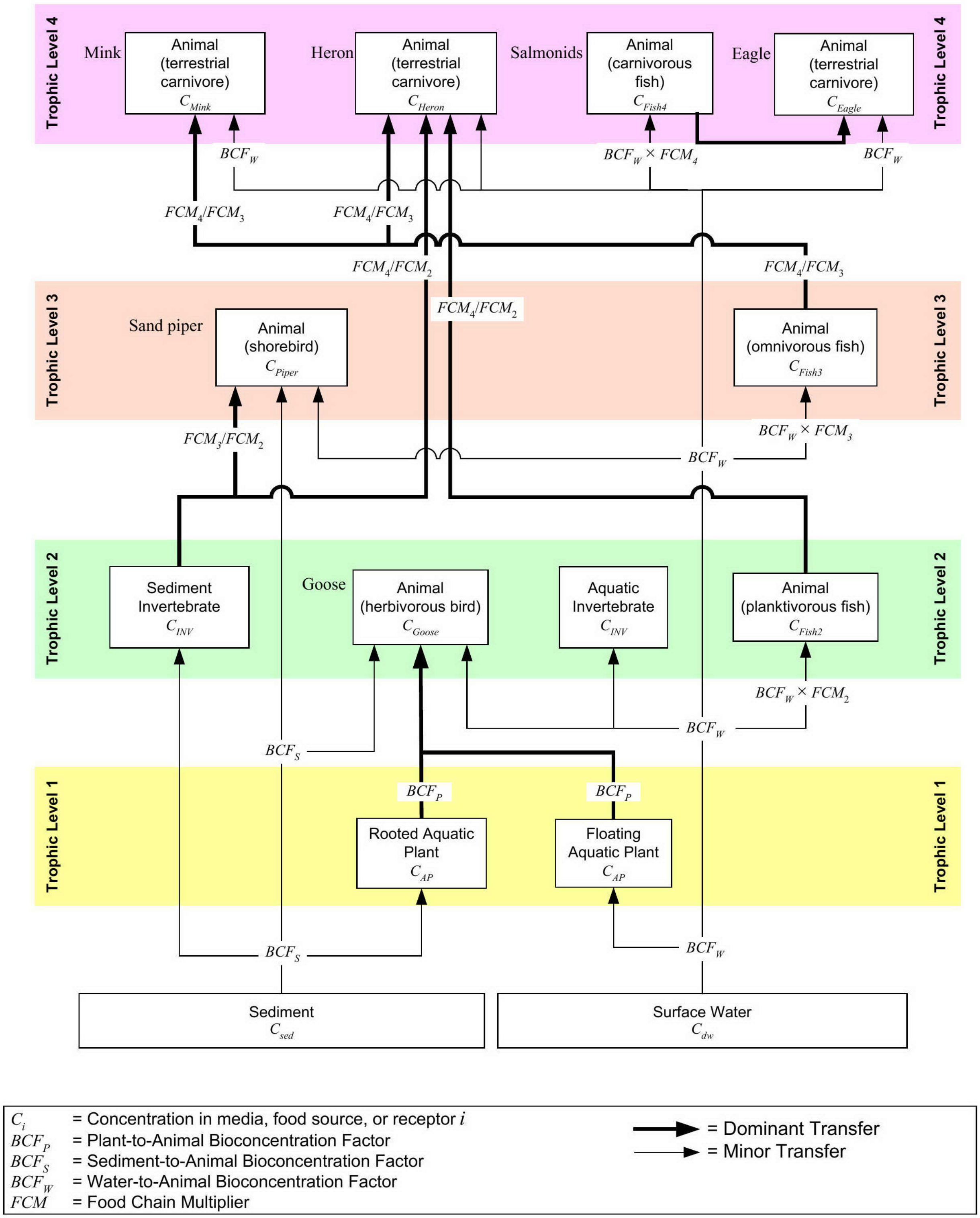
3

1 **Figure 8-12 Relationship Between Sources and Biotransfer Factors for Calculating Terrestrial**
2 **Exposures**



3

Figure 8-13 Relationship Between Sources and Biotransfer Factors for Calculating Aquatic Exposures



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9 Relationship of Risk Assessment to WTP

The intent of the SLRA is to provide information to help assess the impact of potential airborne emissions from the WTP to people who live near or work on or near the Hanford site, to American Indians who use resources on or near the Hanford site, and to plants and animals on or near the Hanford site. It is important that people and the environment are not harmed because potential exposures are overlooked or underestimated. It is also important to maximize the ability of the WTP to treat and immobilize tank wastes and, in doing so, minimize potential release of tank contents into the environment through leaks or spills. A balance of these goals will result through the iterative process of reviewing the RAWP, reviewing and updating environmental parameters for the SLRA and WTP engineering design, and calculating risk-based emission limits, as needed. This iterative process is shown on Figure 2-1.

During the PRA and FRA, any COPCs or ROPCs that exceed risk or hazard thresholds will be evaluated further to determine the driving factors behind the risk and the potential uncertainty associated with them. When the uncertainty associated with exposure parameters and toxicity values becomes reduced as much as possible and when there are exceedances of the thresholds, risk-based emission criteria for COPCs will be evaluated. Engineering design specifications, including changes to feed rate and acceptance criteria, may be revised based on risk-based emission limits. Each major step of the process will include review from regulatory agencies, American Indian tribes, and the public.

To better understand this iterative process, it is important to identify the relationship of the PRA and FRA (Section 9.1), the sources of potential changes that could affect the risk assessments (Section 9.2), and risk-based emission limits (Section 9.3). Each is briefly described below.

9.1 Relationship of the PRA and FRA

The PRA will be reviewed by regulatory agencies, by American Indian tribes, and by the public. Input from all these reviewers will be included in decisions about succeeding steps in the SLRA process, including refinement of the risk assessment assumptions for the FRA.

Both the PRA and FRA are designed to overestimate exposures to human and ecological receptors. To help make risk management decisions, predicted risks and hazards are compared to thresholds. There are thresholds for both human and ecological receptors. If the PRA indicates that total human health risks or hazards to plausible receptors are below the thresholds of 1E-05 (excess cancer risk expressed as ILCR) or 0.25 (HQ and HI), or if ESQs are less than the threshold of 0.25, the process will move on to the FRA following the environmental performance demonstration tests. Additionally, for acute exposure, the human HQ is set at 1.0.

These threshold values are summarized in Table 9-1 and described in Sections 7.4.1 and 7.4.2 (Human Health) and Section 8.4.3 (Ecological). If the PRA indicates that human risks to plausible receptors are greater than 1E-05 (ILCR), or if human noncancer HQs and HIs are greater than 0.25, or if ESQs are greater than 0.25, or if human acute HQs are greater than 1.0, a number of actions will be considered. Potential actions will include reevaluation of conservative exposure parameters for the risk assessment and reevaluation of operating conditions.

9.2 Sources of Potential Changes in the Risk Assessment

A risk assessment represents the status of receptors, facility, and toxicity knowledge at a point in time. If land use changes or if new site-specific data becomes available to replace default exposure assumptions, the assumptions used in the PRA may change. If there are changes in engineering design of the WTP that result in changes in emissions estimates, exposures may change; if site-specific uptake factors for the food chain become available, exposures may change; if there are revisions to toxicity data for some COPCs or ROPCs, ILCR risks and HQs and HIs for those COPCs and ROPCs may change. If any of these changes occur, the SLRA could be revisited to assess potential impacts to public welfare and the environment.

The PRA will evaluate the risks posed by the projected WTP emissions. Assuming these emissions do not pose unacceptable risks they will be incorporated into the DWP. The FRA will evaluate the risks posed by the projected emissions and for the HLW and LAW vitrification systems will evaluate emissions from environmental performance demonstration tests. Assuming these emissions do not pose unacceptable risks they will be incorporated into the WTP Permit replacing the PRA data. If either the PRA or the FRA exceed the thresholds listed in Table 9-1 additional site-specific data will be evaluated including evaluation of anticipated feed composition and projecting operating conditions.

9.3 Risk-Based Emissions Limits

Risk-based emission limits will be developed if risk and hazard thresholds are exceeded and if modification of overly conservative assumptions do not resolve any exceedances. These emission limits will be established following the PRA and the FRA. Risk-based emission limits will be provided for plausible exposure scenarios. Risk-based emission limits will be calculated for any COPC that exceeds risk thresholds in the PRA and FRA. If no individual COPC risks or hazards exceed these thresholds but the total risk or hazard exceeds thresholds, risk-based emission limits will be calculated for the COPCs having the largest contribution to this total risk or hazard. Additional site-specific information, and the results of the environmental performance demonstration test, will be available for the FRA and considered in development of risk-based emissions limits. Risk thresholds that are exceeded will be addressed to the satisfaction of Ecology and EPA and submitted for public comment prior to approval of the PRA and FRA.

9.3.1 Human Health Risk-Based Emission Limits

Risk-based emission limits will be calculated for COPCs with human health risks or hazards to plausible receptors greater than 1E-05 (ILCR) or 0.25 (HQ and HI). If no individual COPC risks or hazards exceed these thresholds but the total risk or hazard exceeds thresholds, risk-based emission limits will be calculated for the COPCs having the largest contribution to this total risk or hazard. Using the same exposure scenarios, pathways, toxicity values, and equations used to calculate plausible risk estimates, acceptable COPC concentrations in various media will be determined such that the corresponding total risk or hazard (across all media) is below the threshold values of 1E-05 (ILCR) and 0.25 (HQ and HI) for each plausible receptor. For acute exposure, the HQ threshold is 1.0. Air dispersion modeling results will then be used to convert these media concentrations to risk-based emission limits.

9.3.2 Ecological Risk-Based Emission Limits

Risk-based emission limits will be calculated for COPCs with ESQs greater than 0.25, or for driver chemicals if the total ESQ is greater than 0.25. Risk-based emission limits will be calculated for a given ecological receptor using the same exposure and food-web assumptions, toxicity values, and equations used to calculate plausible ecological risk estimates. The risk equations will be used to back-calculate acceptable COPC concentrations in various media starting with an ESQ of 0.25. Air dispersion modeling results will then be used to convert these media concentrations to risk-based emissions limits.

9.4 Summary

In summary, the PRA will be submitted for review by regulatory agencies, American Indian tribes, and the public. If the PRA shows risks and hazards below the thresholds, the FRA will be performed and submitted following the environmental performance demonstration tests. If hazards or risks predicted in the PRA are above the thresholds, regulatory authorities will be consulted and the next course of action will be decided. Examples of potential actions are re-evaluating exposure parameters to determine whether the risk assessment was overly conservative and revising the operating plans to reduce emissions. If thresholds are still exceeded in the PRA, then risk-based criteria will be developed. All of these steps will help ensure that WTP operations will be conducted in a manner safe to human and ecological receptors on and near the Hanford site.

Table 9-1 Overview of Risk Thresholds for COPCs and ROPCs in the PRA for the WTP

	Chronic Exposures			Acute Exposures	
	Carcinogens	Noncarcinogens			
Receptor	Incremental Lifetime Cancer Risk (ILCR)	Hazard Quotient or Ecological Screening Quotient (HQ or ESQ)	Hazard Index or Total Ecological Screening Quotient (HI or ESQ)	Acute Hazard Quotient (AHQ)	Acute Hazard Index (AHI)
Chemicals of Potential Concern					
Human	1E-05 or 1 in 100,000	0.25	0.25	1.0	1.0
Plants and Animals	NA	0.25	0.25	NA	NA
Radionuclides of Potential Concern					
Human	1E-05 or 1 in 100,000	NA	NA	1.0	1.0
Plants and Animals	NA	0.25	0.25	NA	NA

NA = Not applicable.

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10 Uncertainty Assessment

Uncertainty or technical doubt is introduced into the human health and ecological risk assessments at every step of the process. As noted by EPA (2005), uncertainty occurs because risk assessment is a complex process, requiring integration of source information, fate and transport in various environments, exposure assessment, and effects assessment. Uncertainty is inherent in the risk assessment process even when the most accurate, up-to-date data and the most sophisticated models are used. Four types of uncertainty are addressed here:

- General (that is, non-effects) parameter uncertainty and variability
- Effects parameter uncertainty and variability
- Model uncertainty
- Decision-rule uncertainty

General parameter uncertainty occurs when variables used in equations cannot be measured precisely or accurately or have not been measured (such as lack of data). Other parameters are measurable and are represented by single fixed values, but actually have variability (such as body weight).

Effects parameter uncertainty and variability are associated with toxicity values (cancer slope factors [*CSF*s] and unit risk factors [*URF*s], reference doses [RfDs] and reference concentrations [*RfC*s] for human receptors, and toxicity reference values [*TRV*s] and benchmarks for ecological receptors), ecological measurement endpoints, and ecological assessment endpoints. Uncertainty occurs as a result of deficiencies in experimental design, extrapolation from experimental conditions to environmental conditions, or complete lack of effects information. Variability occurs as a result of variations in receptor sensitivity due to age, genetics, pre-existing conditions, presence of predators, or other environmental stressors.

Model uncertainty is associated with all models used in all phases of the risk assessments, including air dispersion and other environmental models, animal models used as surrogates for testing human health effects, and dose response models used in extrapolation of laboratory data to human health or ecological effects. All models are simplifications of reality, and therefore exclude some variables to reduce complexity and/or to compensate for missing data. The models identified in this environmental RAWP were selected on the basis of scientific policy because they provide the information needed to conduct the risk assessments and are considered by Ecology and EPA to be state-of-the-science models.

Decision-rule uncertainty arises out of the need to balance different social concerns when determining an acceptable level of risk. Decision-rule uncertainty is associated with the choice of models used, the selection of constituents to be included in the analysis, the default parameter values used, the dependence on single-point estimates of toxicity (human *RfD*s/*RfC*s and *CSF*s/*URF*s and ecological *TRV*s), and the selection of risk and hazard thresholds for evaluating the results of the SLRA.

An overview of the potential sources of uncertainty in the SLRA is provided in Section 10.1. A discussion of how uncertainty will be addressed in the PRA is provided in Section 10.2.

10.1 Sources of Uncertainty in the SLRA

A brief summary of the sources of uncertainty in each step of the risk assessment is provided below. Additional discussion is provided in Sections 4.2, 5.5, 6.8, 7.5, and 8.6 of this RAWP. One or more of the four types of uncertainty described above impact each of these steps.

10.1.1 Identification of Constituents of Potential Concern

The identification of COPCs and ROPCs discussed in Section 4 is uncertain because these constituents are identified before operation of the WTP and must rely on assumptions regarding what may be in the waste feed and what may be produced as products of incomplete combustion (PICs). Test data collected for the FRA during the environmental performance demonstration will reduce, but not eliminate, this uncertainty because this test data will include uncertainty due to tentatively identified compounds (TICs), detection limits, and variations in actual waste feed.

10.1.2 Estimation of Emissions

The primary sources of uncertainty in the emissions estimate are as follows:

- Characterization data that describes the waste feed streams to the WTP PT Facility
- Decontamination efficiency of the air pollution control equipment
- Creation of PICs by the WTP
- Potential impact of upset conditions and abated fugitive emissions on the overall emission rates

10.1.3 Environmental Modeling

Uncertainties are associated with each aspect of the environmental modeling (air-dispersion modeling, soil accumulation modeling, surface water accumulation modeling, sediment accumulation modeling, and plant accumulation modeling). Uncertainties are associated with both the models themselves, because models are simplifications of reality, and with the parameters and data used in the models.

10.1.4 Human Health Risk Assessment

Uncertainties associated with the COPC and ROPC selection, emission rates, and environmental modeling all contribute to the uncertainty in the HHRA. Sources of uncertainty unique to the HHRA are associated with each step of the HHRA: data evaluation, exposure assessment, toxicity assessment, and risk characterization.

Sources of uncertainty in the data evaluation are described above in Sections 10.1.1 and 10.1.2. Sources of uncertainty in the exposure assessment include contaminant concentrations in exposure media, exposure parameter uncertainty and variability in land-use assumptions, and selection of representative receptor populations and exposure parameter values. Sources of uncertainty in the toxicity assessment include effects uncertainty and variability in toxicity values (*RfD*s/*RfC*s and *CSF*s/*URF*s) and toxicity value data gaps, and surrogates to fill some toxicity data gaps. The risk characterization combines the results of the exposure assessment and toxicity assessment. Therefore, all of the uncertainty in these two steps, as well as the steps prior to the exposure assessment (such as environmental modeling), contributes to the uncertainty in the risk characterization. Additional uncertainty in the risk characterization step surrounds the practice of summing risks and hazard results across all chemicals and exposure pathways, regardless of the mode of action. Also, uncertainty is associated with the eventual human health risk and hazard outcomes and their interpretation.

10.1.5 Ecological Risk Assessment

Uncertainties associated with the COPC and ROPC selection, emission rates, and environmental modeling also contribute to the uncertainty in the ERA. Sources of uncertainty unique to the ERA are associated with each of the four inter-related steps of the ERA: problem formulation, exposure assessment, effects assessment, and risk characterization.

Sources of uncertainty in the problem formulation include identification of representative receptor populations and exposure media. Sources of uncertainty in the exposure assessment include exposure parameter uncertainty and variability included in selection of representative exposure parameter values and contaminant concentrations in exposure media. Sources of uncertainty in the effects assessment include effects uncertainty and variability in toxicity values (TRVs and benchmark values) and toxicity value data gaps. The risk characterization combines the results of the exposure assessment and effects assessment. Therefore, all of the uncertainty in these two steps, as well as the steps prior to the exposure assessment (such as environmental modeling) contributes to the uncertainty in the ecological risk characterization. Additional uncertainty in the risk characterization step surrounds the practice of summing hazard results across all chemicals regardless of the mode of action. Also, uncertainty is associated with the eventual ecological risk outcomes and their interpretation.

10.2 Uncertainty Assessment in the PRA

The purpose of the uncertainty assessment is to identify and discuss uncertainty associated with the quantitative estimates of human health and ecological risk for the WTP. This discussion serves to place the risk estimates in proper perspective to allow fully informed risk management decisions.

The EPA (2005) notes that: “The science of risk assessment is evolving; where the science base is incomplete and uncertainties exist, science policy assumptions must be made.” Therefore, it is important for risk assessments of treatment facilities such as the WTP to identify uncertainties in the assessment. To meet this obligation, the PRA report will provide an uncertainty analysis that will include:

- Tables listing the general assumptions in each step of the assessments, the rationale for these assumptions, their potential effect on estimates of risk, and the direction and approximate magnitude of the effect
- An analysis of the key assumptions impacting the COPCs and ROPCs, receptors, and exposure pathways that are risk drivers (such as result in risks above or slightly below the established threshold values)
- An evaluation of several other specific sources of uncertainty associated with gaps in our scientific knowledge, or scientific debates over the most appropriate approaches

Each of these items is addressed in more detail below.

10.2.1 Uncertainty Tables

Tables listing the general assumptions in each step of the assessments, the rationale for these assumptions and their potential effect on estimates of risk (overestimation or underestimation), and the approximate magnitude of the effect (minor or major) will be included in the uncertainty assessment. These tables will focus on categories of assumptions rather than specific assumptions. For example, residential exposure parameters may be included, whereas details of each exposure parameter (such as soil ingestion rate or body weight) will not be included. Examples of the planned table formats and contents are provided as Table 10-1 through Table 10-5.

10.2.2 Uncertainty Analysis of Key Assumptions

In addition to the tables described above, a more detailed analysis of the key assumptions impacting the COPCs and ROPCs, human and ecological receptors, and exposure pathways that are risk drivers (such as a result in risks above or slightly below the established threshold values) will be included in the PRA. Examples of possible scenarios resulting in an analysis of key assumptions for the HHRA and ERA are provided below.

- If the total estimated incremental lifetime cancer risk to a resident at the Hanford offsite maximum is 9E-06 (that is, 9 excess cancers in 1,000,000 people) and slightly below the risk threshold of 1E-05 (that is, 10 excess cancers in 1,000,000 people), the uncertainty analysis will focus on the specific constituents and exposure pathways that result in this risk and any assumptions that could result in the actual risk being higher or lower. For example, if the risk due to ingestion of one COPC in homegrown produce is 8E-06 and the total risk from all other COPCs and pathways is 1E-06, the uncertainty analysis would focus on the models and assumptions used to estimate the concentration of that chemical in plants, the residential produce ingestion assumptions, and the toxicity data for the one chemical of interest. This analysis will serve to evaluate whether this risk estimate is likely to be an overestimate or underestimate of reality, and if so, to what extent.
- If the total ESQ to a Great Basin pocket mouse at the onsite ground maximum is 0.35 (slightly above the hazard threshold of 0.25), the uncertainty analysis will focus on the specific chemicals and specific exposure pathways that result in this hazard and any assumptions that could result in the actual hazard being higher or lower. For example, if the hazard due to ingestion of one COPC in soil invertebrates is 0.20 and the hazard due to ingestion of another COPC in soil invertebrates is 0.10, the uncertainty analysis will focus on whether or not it is appropriate to add the ESQs for these two chemicals, the models and assumptions used to estimate the concentrations of these two chemicals in soil invertebrates, the assumption that the mouse has an exclusive diet of soil invertebrates, and the toxicity data for these two chemicals. This analysis will serve to evaluate whether this hazard estimate is likely to be an over- or underestimate of reality, and if so, to what extent.

These are just two examples of the type of specific uncertainty assessment that may be triggered by the findings of the PRA.

10.2.3 Alternate Exposure Scenarios

10.2.3.1 Future Exposure at the Onsite Ground Maximum Location

The *Record of Decision (ROD): Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (64 FR 61615) indicates that DOE has chosen to implement the DOE Preferred Alternative land-use map which designates the Central Plateau (including the ground-maximum location) geographic area Industrial-Exclusive. This land-use designation is consistent with DOE's current management and operation and allows DOE to continue waste management operations in this area of the site and to expand existing facilities or develop new facilities to meet future mission needs. Although this land-use designation precludes the potential exposure to contaminants from residential occupation at the ground maximum, DOE acknowledges that the *Comprehensive Land-Use Plan* (CLUP) is an ongoing process (DOE 2008). If the land-use designation is modified and potential residential occupation at alternate locations (such as the onsite ground maximum or other parts of the site interior) becomes a possibility, the uncertainty assessment in the PRA will include estimated risks to selected receptors as a result of living at the alternate locations in the future timeframe. This assessment will be performed by incorporating future deposition values into the respective exposure scenarios for the appropriate pathways (incidental soil inhalation/ingestion, homegrown produce and livestock) at the location of interest. Note that future exposure at the onsite ground maximum is considered a worst-case scenario because future development at this location is unlikely due to the presence of other industrial and hazardous waste operations in the 200 Areas.

10.2.3.2 Alternate American Indian Exposure Scenarios

Currently, the only American Indian scenario endorsed by the DOE is the American Indian hunter-gatherer exposure scenario developed for the *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site* (TC&WM EIS, DOE 2012). This exposure scenario has been adapted for use in this SLRA and associated risk assessment results will be reported along with other receptors of interest in the PRA. However, the American Indian scenario described in the TC&MW EIS does not necessarily have the full endorsement of regional American Indian tribes whose treaty rights grant them access to the Hanford site. Accordingly, two alternative American Indian scenarios have been developed for this risk assessment and will be fully evaluated and reported as part of the uncertainty assessment of the PRA. The lifestyle and exposure parameters of the first alternate resident subsistence American Indian are primarily based on data from *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (Harris and Harper 2004), *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments* (Harris 2008), and "A Native American Exposure Scenario" (Harris and Harper 1997). The lifestyle and exposure parameters of the second alternate resident subsistence American Indian are primarily based on data from *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment* (RUDOLFI Inc. 2007). Where these guidance documents omitted necessary information, exposure parameters were established using information published in the EFH (EPA 1997a). Children's exposure parameters were developed by proportioning the child caloric intake reported in the CSEFH (EPA 2008) according to the various proportions of meat, vegetable, roots, etc., in the diet of the adult tribal member as reported in the guidance documents cited above. The specific exposure parameters associated with these two alternate resident subsistent American Indian exposure scenarios are presented in Section 7.1.3.9. Incorporation of these alternate scenarios into the uncertainty assessment of the PRA will provide data of interest for regional tribes without contradicting the American Indian scenario established in the TC&MW EIS.

10.2.4 Other Specific Uncertainty Issues

Several sources of uncertainty associated with gaps in our scientific knowledge or scientific debates over the most appropriate approaches to use are identified throughout this RAWP. These issues, as detailed below, will be discussed in the PRA uncertainty assessment:

- **Offsite Exposure Point Concentrations** – In order to help quantify the degree of conservatism associated with using the 90th percentile of air concentration and deposition values from the offsite grid, the location and species values associated with the point of highest annual total air concentration and deposition will be determined in the uncertainty assessment. Total air concentration ($Conc_{Total}$) and deposition (Dep_{Total}) values for each year and offsite exposure grid node will be computed according to:

$$Conc_{Total} = Cyv_{PT} + Cyv_{LAW} + Cyv_{HLW} + Cyp_{PT_1} + Cyp_{LAW_1} + Cyp_{HLW_1} + Cyp_{PT_1} + Cyp_{LAW_1} + Cyp_{HLW_1}$$

$$\begin{aligned} Dep_{Total} = {} & Dydv_{PT} + Dydv_{LAW} + Dydv_{HLW} + Dywv_{PT} + Dywv_{LAW} + Dywv_{HLW} + \\ & Dydp_{PT_1} + Dydp_{LAW_1} + Dydp_{HLW_1} + Dydp_{PT_{2.5}} + Dydp_{LAW_{2.5}} + Dydp_{HLW_{2.5}} + \\ & Dywp_{PT_1} + Dywp_{LAW_1} + Dywp_{HLW_1} + Dywp_{PT_{2.5}} + Dywp_{LAW_{2.5}} + Dywp_{HLW_{2.5}} \end{aligned}$$

Where

$Conc_{Total}$ = the total air concentration (in $\mu g \cdot s/g \cdot m^3$)

Dep_{Total} = the total deposition (in $s/m^2 \cdot yr$)

other variables as defined in Section 6.1.4.3

A comparison of all years and grid node values will be used to determine the maximum values of $Conc_{Total}$ and Dep_{Total} along with their corresponding grid node coordinates (easting and northing, as represented here by the notation X_{CONC}, Y_{CONC} and X_{DEP}, Y_{DEP}, corresponding to $Conc_{Total}$ and Dep_{Total}, respectively). High values for Cyv, Cyp_1, $Cyp_{2.5}$, $Dydv$, $Dydp_1$, $Dydp_{2.5}$, $Dywv$, $Dywp_1$, and $Dywp_{2.5}$ will derived from the offsite grid points associated with X_{CONC}, Y_{CONC} and X_{DEP}, Y_{DEP} and corresponding EPCs will be computed for comparison to those EPCs computed using 90th percentiles. Implications of this comparison will be presented in the uncertainty assessment of the PRA report.

- **Nursing infant assessment** – Potential risks to nursing infants from dioxin-like compounds will be evaluated by comparing the estimated infant dose of dioxins, furans, and coplanar PCBs from the WTP to the background infant dose of these chemicals throughout the United States. The background infant dose referenced in this RAWP may overestimate current exposures because dioxin exposures in the United States have been decreasing for many years. The source of this value and potential range of background infant doses will be discussed further in the uncertainty assessment of the PRA report. There is currently no consensus regarding the most appropriate single approach to quantitatively evaluate potential risks associated with exposure to dioxin-like compounds by nursing infants. Alternative approaches to the two preferred methods to be used in the PRA (that is, comparison to background and lifetime risk) include calculating infant risks using (1) the estimated infant ADD calculated with a exposure duration equal to the period of breast feeding and an equivalent averaging time, and (2) the estimated infant LADD calculated with a exposure duration equal to the period of breast feeding and a 70-year averaging time. These alternative methods will be presented in the uncertainty assessment of the PRA report.
- **Partial exclusion of dermal pathway from the HHRA** – Dermal exposure pathways (to soil, surface water, or air) will not be included in the PRA, with the exception of the sweat lodge exposure pathway, because dermal exposure pathways have been identified as insignificant contributors to risk in numerous risk assessments prepared or reviewed by EPA for airborne emissions from thermal treatment facilities. If initial PRA results indicate that the soil or surface water ingestion or inhalation pathways result in risks that are borderline (that is, close to the risk or hazard threshold) for any plausible receptor, then dermal exposure to that medium may be included in the PRA. A discussion of the potential impact associated with exclusion of this minor pathway from the quantitative risk assessment will be included in the uncertainty assessment of the PRA.
- **Evaluation of PAHs** – Potential human cancer risks associated with 7 polycyclic aromatic hydrocarbons (PAHs) considered to be carcinogenic by EPA (1993) will be evaluated using a RPF approach. The RPFs for an additional 15 PAHs are available from the California (Cal EPA 1999). If the total estimated risk from PAHs is near 1E-05, these additional 15 PAHs will be considered in the uncertainty analysis.
- **Dioxin slope factor** – Potential human cancer risks associated with dioxins and coplanar PCBs will be evaluated using the cancer *CSF* of 1.0E+06 $(mg/kg\text{-}day)^{-1}$ proposed in the *Exposure and Human*

Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds (EPA 2003), and as suggested by Ecology and EPA Region 10 (CCN 063809). While this proposed *CSF* has not yet been approved by EPA, it is more conservative than the current *CSF* published in the HEAST (EPA 1997b). A discussion of comparative risk results will appear in the uncertainty section of the PRA.

- **Toxicity data gaps** – The COPCs without toxicity values (*RfD*, *RfC*, *CSF*, *URF*, *TRV*, ecological benchmarks) cannot be included in the quantitative risk assessments. The potential impact of these COPCs on the risk results will be discussed in the uncertainty assessment.
- **Route-To-Route Extrapolations** – Uncertainties are associated with the estimation of dermal toxicity values from oral values. The *URF* and RfC_{inh} derived from the CSF_{inh} and RfD_{inh} using the conversion in WAC 173-340-708(7)b will have uncertainty if the respiratory deposition and absorption characteristics of the gases and inhaled particles is unknown. Constituents for which a route-to-route extrapolated toxicity was used will be identified and a qualitative discussion of the impact will be included.
- **Radiation benchmarks** – The whole-organism radiation benchmarks for ecological receptors identified in this RAWP have uncertainty associated with them, because they do not take into account effects on sensitive tissues, critical organ effects, relative biological effectiveness, and microdosimetry issues. These issues are currently being investigated by the scientific community and will be mentioned in the uncertainty assessment.
- **Microdosimetry of radionuclides** – Possible synergistic effects of multiple radionuclides and microdosimetry to root hairs, eggs, embryos, and so forth for ecological receptors are currently being investigated and developed by researchers. The current status of this research will be mentioned in the uncertainty discussion in the PRA.
- **Exclusion of external alpha radiation** – The possible effects of external alpha radiation on ecological receptors will be included in the uncertainty assessment of the PRA because external alpha radiation should add only insignificantly to the whole-body dose for organisms (Blaylock and others 1993). The potential impact of omitting alpha radiation will be identified in the uncertainty assessment.
- **Summations of risks** – The PRA will include summations of the total COPC and ROPC risks and hazards as listed below:
  - Total cancer risk to human receptors from all COPCs
  - Total cancer risk to human receptors from all ROPCs
  - Total HI for human receptors from all COPCs
  - Total ESQ for ecological receptors from all COPCs
  - Total ESQ for ecological receptors from all ROPCs

These total risk and hazard calculations will be based on the assumption that the effects of all COPCs or ROPCs to a given receptor are summed. If risk or hazard thresholds are exceeded, a segregation of the constituents by toxicological mode of action and endpoint will be considered. If segregation by toxicological mode of action or endpoint is used, chemical groupings by endpoint will be assigned with approval by Ecology and EPA.

These issues, associated with gaps in our scientific knowledge or with scientific debates over the most appropriate approaches, and any other issues identified while conducting the PRA, will be included in the PRA uncertainty assessment.

10.3 Summary of Uncertainty Assessment

Uncertainty is inherent in every step of the risk assessment process. An uncertainty assessment will be included in the PRA to (1) identify sources of uncertainty associated with the quantitative estimates of human health and ecological risk from the WTP, (2) estimate the potential magnitude of key uncertainties that could influence the results of the PRA, and (3) show other analyses associated with data gaps and scientific discussion. The uncertainty assessment will be used to place the risk estimates in proper perspective to allow fully informed risk management decisions.

10.4 References

10.4.1 Project Documents

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Table 10-1 Example of Sources of Uncertainty in Identification of COPCs and ROPCs

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b]		
		Over-estimation	Not defined	Under-estimation
Tank characterization data	Constituents identified in tank waste are included as COPCs and ROPCs.			
Nondetected constituents	Constituents not detected in tank waste but which may have been used at Hanford are included as COPCs and ROPCs.			
PICs identified in bench-scale testing	Constituents identified in bench-scale testing are included as COPCs and ROPCs.			
PICs identified at hazardous waste combustion facilities	Constituents identified in emissions from hazardous waste combustion facilities are included as COPCs and ROPCs.			

[a] This is an example of the information to be included in the uncertainty table in the PRA report and is not intended to be inclusive of all sources of uncertainty.

[b] These columns will indicate whether the assumption used to compensate for the uncertainty is likely to overestimate or underestimate the actual risk, or whether the direction cannot be identified. The potential magnitude of this impact will be identified as minor (+, o, -) or major (++, oo, --).

Table 10-2 Example of Sources of Uncertainty in Emissions Estimate

		Potential Direction and Magnitude of Risk[b]		
Examples of Sources of Uncertainty	**Description**	**Over-estimation**	**Not defined**	**Under-estimation**
Starting concentration of constituents in tank waste	Identified organics are multiplied by a scaling factor to adjust for unidentified organics.			
	Tanks assumed to have highest organic concentration were used for analysis.			
Throughput of treatment system	System is assumed to run at full capacity for 40 years.			
Efficacy of pollution control equipment	Removal is based on engineering design and assumptions rather than measured values			
Assignment of phase	Each COPC and ROPC is assumed to be present as either vapor, particulate, or particulate-bound. Some constituents may be present as a combination of phases.			
Default upset factors for vapor-phase emissions	Default upset factors are based on recorded operating conditions at hazardous waste combustion units.			

[a] This is an example of the information to be included in the uncertainty table in the PRA report and is not intended to be inclusive of all sources of uncertainty.

[b] These columns will indicate whether the assumption used to compensate for the uncertainty is likely to overestimate or underestimate the actual risk, or whether the direction cannot be identified. The potential magnitude of this impact will be identified as minor (+, o, -) or major (++, oo, --).

Table 10-3 Example of Sources of Uncertainty in Environmental Modeling

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b]		
		Over-estimation	Not defined	Under-estimation
Air Dispersion Modeling				
COPC and ROPC lists	All COPCs and ROPCs are modeled; therefore, uncertainty in this list will be carried into the air dispersion modeling.			
Emission Rates of COPCs and ROPCs	Estimated emission rates are the starting point for predicting airborne dispersion; therefore, uncertainty in these estimates will be carried into the air dispersion modeling.			
Use of CALPUFF air dispersion model	Simulation of the atmospheric dispersion of emissions is limited by data limitations and simplifications inherent in the model.			
Surface meteorological data for 01 January 2002 through 31 December 2006	This is considered representative of long-term conditions.			
Particle size distribution	Particle size influences deposition. Particle sizes of 1 µm and 2.5 µm are assumed.			
Land use and terrain data	Data represents land uses at a point in time, with terrain resolution that varies from 70 m to 90 m, with an absolute accuracy of 130 m in the horizontal and 30 m in the vertical.			
Soil Accumulation Modeling				
COPC and ROPC list	All COPCs and ROPCs are modeled; therefore, uncertainty in this list will be carried into the soil accumulation modeling.			
Emission rates of COPCs and ROPCs	Estimated emission rates are the starting point for predicting airborne dispersion and air dispersion is the starting point for predicting soil concentrations; therefore, uncertainty in these estimates will be carried into the soil accumulation modeling.			
Constituent deposition rates	Air dispersion is the starting point for predicting soil concentrations; therefore, uncertainty in these estimates will be carried into the soil accumulation modeling.			

Table 10-3 Example of Sources of Uncertainty in Environmental Modeling

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b]		
		Over-estimation	Not defined	Under-estimation
Descriptive soil parameters	Parameters such as mixing depth, bulk density, and volumetric water content, which are assigned a single value, may vary widely over a relatively small area.			
Soil loss mechanisms – degradation	COPCs in soil are subject to loss due to biotic and abiotic degradation; however, transformation and subsequent increase of secondary COPCs are not considered in the assessment.			
	Degradation rates, which are assigned a single value, generally from laboratory testing, may vary widely under environmental conditions.			
Surface Water and Sediment Accumulation Modeling				
COPC and ROPC list	All COPCs and ROPCs are modeled; therefore, uncertainty in this list will be carried into the surface water and sediment modeling.			
Emission rates of COPCs and ROPCs	Estimated emission rates are the starting point for predicting airborne dispersion and air dispersion is the starting point for predicting surface water concentrations; therefore, uncertainty in these estimates will be carried into the surface water and sediment modeling.			
Constituent deposition rates	Air dispersion is the starting point for predicting surface water concentrations; therefore, uncertainty in these estimates will be carried into the surface water and sediment modeling.			
Surface water and sediment model	Equations used to model the fate of COPCs and ROPCs deposited into the water body greatly simplify the mechanisms occurring within such a dynamic system.			
Deposition area	The maximum deposition of COPCs and ROPCs is assumed over the entire depositional area of the water body.			
Descriptive surface water and sediment parameters	Parameters such as depth of water column and depth of upper benthic sediment layer, which are assigned a single value, may vary widely.			

Table 10-3 Example of Sources of Uncertainty in Environmental Modeling

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b]		
		Over-estimation	Not defined	Under-estimation
Plant Accumulation Modeling				
COPC and ROPC list	All COPCs and ROPCs are modeled; therefore, uncertainty in this list will be carried into the plant modeling.			
Emission rates of COPCs and ROPCs	Estimated emission rates are the starting point for predicting environmental concentrations; therefore, uncertainty in these estimates will be carried into the plant modeling.			
Air dispersion modeling	Airborne concentrations are the starting point for predicting direct uptake from air; therefore, uncertainty in these estimates will be carried into the plant modeling.			
Constituent deposition rates	Deposition is the starting point for predicting plant concentrations from direct deposition; therefore, uncertainty in these estimates will be carried into the plant modeling.			
Soil accumulation modeling	Soil concentration is the starting point for predicting uptake into plants; therefore, uncertainty in these estimates will be carried into the plant modeling.			
Plant uptake factors	Air-to-plant and soil-to-plant uptake factors, which are assigned a single value, generally from laboratory testing of a limited number of chemicals, may vary widely depending on constituent, plant species, and environmental conditions.			
Descriptive plant parameters	Parameters such as length of growing season and yield, which are assigned a single value, may vary widely among plant species and agricultural practices.			

[a] This is an example of the information to be included in the uncertainty table in the PRA report and is not intended to be inclusive of all sources of uncertainty.

[b] These columns will indicate whether the assumption used to compensate for the uncertainty is likely to overestimate or underestimate the actual risk, or whether the direction cannot be identified. The potential magnitude of this impact will be identified as minor (+, o, -) or major (++, oo, --).

Table 10-4 Example of Sources of Uncertainty in Human Health Risk Assessment[a]

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b]		
		Over-estimation	Not defined	Under-estimation
Exposure Assessment				
COPC and ROPC list	All COPCs and ROPCs are modeled; therefore, uncertainty in this list will be carried into the HHRA.			
Emission Rates of COPCs and ROPCs	Estimated emission rates are the starting point for predicting environmental concentrations; therefore, uncertainty in these estimates will be carried into the HHRA.			
Air dispersion modeling	Airborne concentrations are the starting point for predicting inhalation exposures; therefore, uncertainty in these estimates will be carried into the HHRA			
Soil accumulation modeling	Soil concentration is the starting point for predicting soil ingestion exposures and uptake into foodstuffs; therefore, uncertainty in these estimates will be carried into the HHRA.			
Surface water accumulation modeling	Surface water concentration is the starting point for predicting drinking water, fish ingestion, and sweat lodge exposures; therefore, uncertainty in these estimates will be carried into the HHRA.			
Plant accumulation modeling	Plant concentration is the starting point for predicting produce ingestion exposures and concentrations in animal products; therefore, uncertainty in these estimates will be carried into the HHRA.			
Exposure parameters	Exposure parameters are a combination of average (such as body weight) and upper-bound (such as soil ingestion) point estimates of parameters that vary widely among individuals.			
Toxicity Assessment				
Cancer slope factors (*CSF*s) for COPCs	*CSF*s are a plausible upper-bound estimate of the probability of a cancer, per unit intake of a chemical, over a lifetime. Most chemical *CSF*s are based on animal data.			
Cancer slope factors for ROPCs	*CSF*s are central estimates of the age-averaged, lifetime radiation cancer incidence risk and are based on human data.			

Table 10-4 Example of Sources of Uncertainty in Human Health Risk Assessment[a]

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b] Over-estimation	Not defined	Under-estimation
Risk Characterization				
Exposure assessment	All uncertainties in the exposure assessment are carried into the risk characterization.			
Toxicity assessment	All uncertainties in the toxicity assessment are carried into the risk characterization.			
Additivity of COPC cancer risk	The assumption of additivity of COPC cancer risk assumes intakes of individual chemicals are small, and there is no interaction among chemicals.			
Additivity of ROPC cancer risk	The assumption of additivity of ROPC cancer risk is much less uncertain than for COPCs because the mode of action is the same for all radionuclides.			
Additivity of COPC hazard quotients	The assumption of additivity is likely to overestimate risk since many chemicals act on different target organs.			

[a] This is an example of the information to be included in the uncertainty table in the PRA report and is not intended to be inclusive of all sources of uncertainty.

[b] These columns will indicate whether the assumption used to compensate for the uncertainty is likely to overestimate or underestimate the actual risk, or whether the direction cannot be identified. The potential magnitude of this impact will be identified as minor (+, o, -) or major (++, oo, --).

[c] In this context, residential receptors include resident (adult and child), resident subsistence farmer (adult and child), resident fisher (adult and child), Native American subsistence resident (adult and child), and the residential portion of the Hanford Site industrial worker exposure.

Table 10-5 Example of Sources of Uncertainty in Ecological Risk Assessment[a]

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b]		
		Over-estimation	Not defined	Under-estimation
Problem Formulation				
Identification of ecological receptors	Receptors are identified to represent various feeding guilds and trophic levels.			
Choice of assessment endpoints	Endpoints are chosen to represent key species in the Hanford Site ecosystem.			
Choice of measurement endpoints	Endpoints are chosen to represent significant deleterious effects to ecological receptors.			
Exposure Assessment				
COPC and ROPC list	All COPCs and ROPCs are modeled; therefore, uncertainty in this list will be carried into the ERA.			
Emission Rates of COPCs and ROPCs	Estimated emission rates are the starting point for predicting environmental concentrations; therefore, uncertainty in these estimates will be carried into the ERA.			
CALPUFF air dispersion modeling	Airborne concentrations are used to predict environmental concentrations; therefore, uncertainty in these estimates will be carried into the ERA.			
Soil accumulation modeling	Soil concentration is the starting point for predicting soil ingestion exposures and uptake into food; therefore, uncertainty in these estimates will be carried into the ERA.			
Surface water and sediment accumulation modeling	Surface water and sediment concentrations are the starting point for predicting exposure to aquatic biota; therefore, uncertainty in these estimates will be carried into the ERA.			
Plant accumulation modeling	Plant concentration is the starting point for predicting plant ingestion exposures and concentrations in higher trophic levels; therefore, uncertainty in these estimates will be carried into the ERA.			
Food chain multiplier (FCM) approach for aquatic receptors	The challenge of extrapolating from one aquatic species to another will be identified.			
FCM approach for terrestrial receptors	The challenge of extrapolating from aquatic species (which make up the database for FCMs) to terrestrial food chains will be identified.			

Table 10-5 Example of Sources of Uncertainty in Ecological Risk Assessment[a]

Examples of Sources of Uncertainty	Description	Potential Direction and Magnitude of Risk[b] Over-estimation	Not defined	Under-estimation
Exclusive diets	Exclusive diets mathematically make the animal too dependant on one food source (whether plants or animals). This represents a large departure from realistic real diets for desert omnivores.			
Exposure parameters	Exposure parameters are a combination of average and upper-bound point estimates of parameters that vary widely among individuals.			
Effects Assessment				
Toxicity reference values for terrestrial receptors	Toxicity thresholds are based on concentrations reported to have no, or little, effect on the test organism or are estimated conservatively from published toxicity data.			
Toxicity reference values for aquatic receptors	Toxicity thresholds are based on concentrations reported to have no, or little, effect on the test organism or are estimated conservatively from published toxicity data.			
Risk Characterization				
Exposure assessment	All uncertainties in the exposure assessment are carried into the risk characterization.			
Effects assessment	All uncertainties in the effects assessment are carried into the risk characterization.			
Additivity of COPC hazard quotients	The assumption of additivity is likely to overestimate risk since many chemicals act on different target organs.			

[a] This is an example of the information to be included in the uncertainty table in the PRA report and is not intended to be inclusive of all sources of uncertainty.

[b] These columns will indicate whether the assumption used to compensate for the uncertainty is likely to overestimate or underestimate the actual risk, or whether the direction cannot be identified. The potential magnitude of this impact will be identified as minor (+, o, -) or major (++, oo, --).

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Appendix A

Supporting Equations for Accumulation Modeling and Derivation of Selected Parameters

Appendix A
Supporting Equations for Accumulation Modeling and Derivation of Selected Parameters

Contents

Tables

Figures

A.1 Introduction

This appendix provides supplemental equations to the equations provided in Section 6 (Environmental Modeling) of this work plan. The equations and parameters in this appendix are from the US Environmenal Protection Agency's (EPA) *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP) (EPA 2005). Equations that support the soil, surface water, and sediment accumulation modeling and data are provided in this appendix. Equations in Section 6 refer to the immediate supporting equations within this appendix. Parameters that are functions of other parameters are presented only in this appendix (e.g., the equation for the soil loss constant due to biotic and abiotic degradation, presented below, is referenced in the definition of parameters used to estimate the total soil loss constant, which is referenced in subsequent equations). Section 6 presents only the "high-level" equations; all supporting equations (including supporting equations for parameters that appear in other supporting equations) are presented in this appendix. A description of how the parameters shown in this appendix link to the equations in Section 6 is provided for each equation in this appendix.

Because many of the equations used in the soil modeling are functions of other equations, the intermediary calculations necessary to calculate the chemical of potential concern (COPC) or radionuclide of potential concern (ROPC) concentrations in soil should be performed in a logical order. The equations for these intermediary calculations can be found in this appendix; values for the contaminant-specific parameters are presented in Supplement 4. The order for these intermediary calculations is as follows:

1 Estimate individual COPC and ROPC soil-loss mechanisms. These include soil loss constant due to biotic and abiotic degradation (Eq. A-2-13 in HHRAP), soil loss constant due to radiological decay (Eq. A-2-13 in HHRAP), soil loss constant due to leaching (Eq. 5-5A in HHRAP), soil loss constant due to surface runoff (Eq. 5-4 in HHRAP), soil loss constant due to volatilization (Eq. 5-6 in HHRAP), and soil loss constant due to soil erosion (Eq. 5-3 in HHRAP). These soil loss mechanisms are estimated using methods provided in EPA (2005), along with Hanford-specific parameter values (a site-specific parameter value unique to the Hanford Site), site-specific parameter values (a parameter unique to a site and independent of the constituent being evaluated; the actual value may be a default value and not specific to the Hanford Site), and contaminant-specific parameter values (a parameter unique to a contaminant and independent of the site being evaluated) where appropriate (see Table 6-3 for Hanford-specific and site-specific parameter values, and Supplement 4 for contaminant-specific parameter values).

2 Compute the total soil loss (summing across all available soil loss mechanisms) for each soil depth (untilled soil, root zone soil, and tilled soil) (Eq. 5-2A in HHRAP).

3 Calculate the deposition term (denoted by *Ds*) used to estimate the soil concentration (Eq. 5-11 or Table B-1-1 in HHRAP). Note that for mercury, the deposition term to soil is modeled slightly differently from all other COPCs (as specified in HHRAP). Table B-1-1 in HHRAP provides supplemental equations used to estimate *Ds* for total mercury, divalent mercury, and methyl mercury. The deposition term to soil is estimated using methods provided in EPA (2005), along with site-specific parameter values where appropriate (see Supplement 4).

4 Calculate soil concentrations (Eqs. 5-1C through 5-1E in HHRAP, and Section 6.2). The soil concentrations are estimated using methods provided in EPA (2005), along with site-specific parameter values where appropriate (see Table 6-3 for a list of site-specific parameter values used in soil modeling).

The following sections present specific equations to support the soil, surface water, and sediment accumulation modeling.

A.2 Soil Losses

A.2.1 Soil Loss Due to Leaching (*ksl*)

Soil loss due to leaching (*ksl*) is a function of the amount of water available to generate leachate and soil properties, such as bulk density, soil moisture, soil porosity, and soil sorption properties. Equation 5-5A (Table B-1-5) in the HHRAP is used to calculate the soil loss constant due to leaching for COPCs and ROPCs. The *ksl* is used in the estimation of the total soil loss constant (see Eq. 5-2A in the HHRAP), which is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to estimate ks_l is as follows:

$$ksl = \frac{P + I - RO - E_v}{\theta_{sw} \cdot Z_s \cdot [1 + (Kd_s \cdot BD / \theta_{sw})]} \qquad \text{(Eq. 5-5A in HHRAP)}$$

where:

ksl	=	COPC or ROPC soil loss constant due to leaching (yr^{-1}). *ksl* is constituent-specific and depth-specific. If no *ksl* value exists for a constituent, the model uses $ksl = 0\ yr^{-1}$.
P	=	average annual precipitation (cm/yr). A value of 18.19 cm/yr (7.16 in./yr for Richland, Washington [Western Regional Climate Center 2002]) is used.
I	=	average annual irrigation (cm/yr). A value of 0 cm/yr is used (assumed value).
RO	=	average annual surface runoff from pervious areas (cm/yr). *RO* is site-specific. A value of 2.5 cm/yr (estimated value, assuming that the majority of rainfall recharges or evaporates) is used.
E_v	=	average annual evapotranspiration (cm/yr). E_v is site-specific. A value of 16.8 cm/yr is used (Wisiol 1984, Table 2).
θ_{sw}	=	soil volumetric water content (mL water/cm^3 soil). θ_{sw} is site-specific. The recommended default value of 0.2 mL/cm^3 is used (Eq. 5-5A of the HHRAP).
Z_s	=	soil mixing zone depth (cm). Three different values (depths) are used for Z_s: untilled soil (2 cm), root-zone soil (15 cm), and tilled soil (20 cm).
Kd_s	=	soil-water partition coefficient (mL water/g soil). Kd_s is constituent-specific. If no Kd_s value exists for an organic constituent, then Kd_s is estimated using Eq. A-2-10 in the HHRAP and a $f_{oc} = 0.0044$ (fraction of organic carbon in soil, site-specific value from average organic carbon measurements [CCN 150854]), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_s is not available and cannot be estimated, the model uses $Kd_s = 0$ mL/g.

BD = soil bulk density (g soil/cm^3 soil). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al. 1998).

A.2.2 Loss Constant Due to Runoff (*ksr*)

Equation 5-4 (Table B-1-4) in EPA (2005) can be used to calculate the soil-loss constant due to surface runoff (*ksr*) for COPCs and ROPCs. The *ksr* is used in the estimation of the total soil loss constant (see Eq. 5-2A in the HHRAP), which is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to estimate *ksr* is as follows:

$$ksr = \left(\frac{RO}{\theta_{sw} \cdot Z_s}\right) \cdot \left(\frac{1}{1 + (Kd_s \cdot BD/\theta_{sw})}\right) \qquad \text{(Eq. 5-4 in HHRAP)}$$

where:

ksr = COPC or ROPC soil loss constant due to surface runoff (yr^{-1}). *ksr* is constituent and depth-specific.

RO = average annual surface runoff from pervious areas (cm/yr). *RO* is site-specific. A value of 2.5 cm/yr is used (estimated value, assuming that the majority of rainfall recharges or evaporates).

θ_{sw} = soil volumetric water content (mL water/cm^3 soil). θ_{sw} is site-specific. The recommended default value of 0.2 mL/cm^3 is used (Eq. 5-5A of the HHRAP).

Z_s = soil mixing zone depth (cm).

Kd_s = soil-water partition coefficient (mL water/g soil). Kd_s is constituent-specific. If no Kd_s value exists for an organic constituent, then Kd_s is estimated using Eq. A-2-10 in the HHRAP and a f_{oc} = 0.0044 (fraction of organic carbon in soil, site-specific value from average organic carbon measurements [CCN 150854]), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_s is not available and cannot be estimated, the model uses Kd_s = 0 mL/g.

BD = soil bulk density (g soil/cm^3 soil). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al.1998).

Since neither natural precipitation nor irrigation provide adequate water to generate surface runoff (refer to Section 6.2), the soil loss constant due to surface runoff is set to zero.

A.2.3 Loss Constant Due To Volatilization (*ksv*)

Volatile and semivolatile organic COPCs, as well as mercury, emitted in high concentrations may become adsorbed to soil particles and exhibit volatilization losses from soil (*ksv*). This soil loss is a function of the rate of movement of the constituents to the soil surface, the chemical vapor concentration at the soil surface, and the rate at which vapor is carried away by the atmosphere. Equation 5-7A (Table B-1-6) in the HHRAP is used to calculate the soil loss constant due to volatilization for organic COPCs and mercury (*ksv* is assumed to be zero for ROPCs and inorganic COPCs (except for mercury) since these constituents are not considered to be volatile). The *ksv* is used in the estimation of the total soil loss constant, *ks* (see Eq. 5-2A in the HHRAP), which is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP).

The equation to estimate *ksv* is as follows:

$$ksv = \left(\frac{CF \cdot H}{Z_s \cdot Kd_s \cdot R \cdot T_a \cdot BD}\right) \cdot \left(\frac{D_a}{Z_s}\right) \cdot \left[1 - \frac{BD}{\rho_{soil}} - \theta_{sw}\right] \qquad \text{(Eq. 5-7A in HHRAP)}$$

where:

- *ksv* = COPC soil loss constant due to volatilization (yr^{-1}). *ksv* is constituent-specific. If no *ksv* value can be calculated for a constituent, then the soil loss due to volatilization (*ksv*) is assigned a value of 0 yr^{-1}.
- *CF* = units conversion factor of 3.1536E+07 (s/yr).
- *H* = Henry's Law Constant (atm·m³/mol). If no value is available for *H*, then it is calculated using Eq. A-2-3 in the HHRAP if constituent vapor pressure and water solubility data are available (see Supplement 4). If *H* cannot be determined, then the soil loss due to volatilization (*ksv*) is assigned a value of 0 yr^{-1}.
- Z_s = soil mixing zone depth (cm). Three different values (depths) are used for Z_s: untilled soil (2 cm), root-zone soil (15 cm), and tilled soil (20 cm).
- Kd_s = soil-water partition coefficient (mL water/g soil). Kd_s is constituent-specific. If no Kd_s value exists for an organic constituent, then Kd_s is estimated using Eq. A-2-10 in the HHRAP and a f_{oc} = 0.0044 (fraction of organic carbon in soil, site-specific value from average organic carbon measurements [CCN 150854]), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_s is not available and cannot be estimated, the model uses Kd_s = 0 mL/g.
- *R* = universal gas constant ($atm{\cdot}m^3/mol{\cdot}°K$). A value of $R = 8.205\times10^{-5}$ $atm{\cdot}m^3/mol{\cdot}°K$ is used.
- T_a = ambient air temperature (°K). T_a is site-specific and an average value of 286 °K is used (PNNL 2003. 2004, 2005a, 2006, 2007).
- *BD* = soil bulk density (g soil/cm³ soil). A site-specific value of 1.3 g/cm³ is used (Halvorson et al.1998).
- D_a = diffusion coefficient of contaminant in air (cm^2/s). D_a is constituent-specific (see Supplement 4). If D_a is not available, it can be estimated using Eqs. A-2-4 and A-2-6 in the HHRAP. If no value is available for D_a, and if it cannot be estimated, then *ksv* is not calculated and the soil loss due to volatilization is assigned a value of 0 yr^{-1}.
- ρ_{soil} = Solids particle density (g/cm³). The recommended default value of 2.7 g/cm³ is used.
- θ_{sw} = Soil volumetric water content (mL/cm³ soil). θ_{sw} is the volumetric fraction of water retained in soil. The recommended default value of 0.2 mL/cm³ is used.

All default values are from Eq. 5-7A in the HHRAP, unless otherwise specified.

A.2.4 Loss Constant Due to Soil Erosion (*kse*)

Equation 5-3 (HHRAP, Table B-1-3) in the HHRAP is used to calculate the soil loss constant due to soil erosion (*kse*) for COPCs. The *kse* is used in the estimation of the total soil loss constant, *ks* (see Eq. 5-2A in the HHRAP), which is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to estimate *kse* is as follows:

$$ks_e = \left(\frac{CF \cdot X_e \cdot SD \cdot ER}{BD \cdot Z_s}\right) \cdot \left(\frac{Kd_s \cdot BD}{\theta_{sw} + (Kd_s \cdot BD)}\right) \quad \text{(Eq. 5-3 in HHRAP)}$$

where:

kse	=	COPC soil loss constant due to soil erosion (yr^{-1}). *kse* is constituent-specific and depth-specific.
CF	=	units conversion factor of 0.1 ($g \cdot m^2/kg \cdot cm^2$).
X_e	=	unit soil loss ($kg/m^2 \cdot yr$). X_e is site-specific and calculated in Eq. 5-33A in the HHRAP.
SD	=	watershed sediment delivery ratio (unitless). *SD* is site-specific and is calculated in Eq. 5-34 in the HHRAP.
ER	=	soil enrichment ratio (unitless). *ER* is site-specific. The following recommended values (EPA 2005) are used: 3 for organic COPCs and 1 for inorganic COPCs.
BD	=	soil bulk density (g soil/cm^3 soil). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al. 1998).
Z_s	=	soil mixing zone depth (cm).
Kd_s	=	soil-water partition coefficient (mL water/g soil). Kd_s is constituent-specific. If no Kd_s value exists for an organic constituent, then Kd_s is estimated using Eq. A-2-10 in the HHRAP and a f_{oc} = 0.0044 (fraction of organic carbon in soil, site-specific value from average organic carbon measurements [CCN 150854]), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_s is not available and cannot be estimated, the model uses Kd_s = 0 mL/g.
θ_{sw}	=	soil volumetric water content (mL water/cm^3 soil). θ_{sw} is site-specific.

Since neither natural precipitation nor irrigation provide adequate water to cause surface erosion (refer to Section 6.3), the soil loss constant due to erosion is set to zero.

A.2.5 Soil Loss Constant (*ks*)

Equation 5-2A (HHRAP Table B-1-2) in the HHRAP calculates the total soil loss constant (*ks*) due to biotic and abiotic degradation, radiological decay, leaching, surface runoff, volatilization, and erosion. The *ks* is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The site-specific equation to estimate *ks* for all constituents (modified from Eq. 5-2A the HHRAP to include soil loss from radiological decay) is as follows:

$$ks = ksg + kse + ksr + ksl + ksv + k_{decay} \quad \text{(modified Eq. 5-2A in HHRAP)}$$

where:

ks	=	total constituent soil loss constant due to biotic and abiotic degradation, radiological decay, leaching, surface runoff, volatilization, and erosion (yr^{-1}). *ks* is constituent-specific, site-specific, and depth-specific. If no *ks* value exists for a constituent, the model uses *ks* = 0 yr^{-1}.

ksg = COPC soil loss constant due to biotic and abiotic degradation (yr^{-1}). *ksg* is COPC-specific, site-specific, and calculated in Eq. A-2-13 in the HHRAP for COPCs (but not for ROPCs). If no *ksg* value exists for a constituent, the model uses $ksg = 0\ yr^{-1}$.

kse = Since neither natural precipitation nor irrigation provide adequate water to generate erosion (refer to Section 6.2), the model uses $kse = 0\ yr^{-1}$.

ksr = Since neither natural precipitation nor irrigation provide adequate water to generate surface runoff (refer to Section 6.2), the model uses $ksr = 0\ yr^{-1}$.

ksl = constituent soil loss constant due to leaching (yr^{-1}). *ksl* is constituent-specific, site-specific, depth-specific, and is calculated in Eq. 5-5A in the HHRAP. If no *ksl* value exists for a constituent, the model uses $ksl = 0\ yr^{-1}$.

ksv = constituent soil loss constant due to volatilization (yr^{-1}). *ksv* is constituent-specific, site-specific, depth-specific, and is calculated in Eq. 5-7A in the HHRAP. If no *ksv* value exists for a constituent, the model uses $ksv = 0\ yr^{-1}$.

k_{decay} = ROPC radiological decay constant (yr^{-1}). k_{decay} is ROPC-specific, site-specific, and calculated by using the decay half-life in Eq. A-2-13 in the HHRAP for ROPCs (but not for COPCs). If no k_{decay} value exists for a constituent, the model uses $k_{decay} = 0\ yr^{-1}$.

A.3 Soil Terms and Concentration

A.3.1 Deposition Term (*Ds*)

Equations in Table B-1-1 in the HHRAP are used to calculate the soil deposition term used in soil modeling (*Ds*) for all COPCs. *Ds* is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to calculate *Ds* is as follows:

$$Ds = \frac{Q \cdot CF}{Z_s \cdot BD} \cdot \left[F_v \cdot (Dydv + Dywv) + (Dydp + Dywp) \cdot (1 - F_v) \right] \qquad \text{(Table B-1-1 in HHRAP)}$$

where:

Ds = deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.

Q = constituent-specific emission rate (g/s for COPCs, Ci/s for ROPCs). *Q*, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific, and stack-specific. If no *Q* value exists for a constituent, the model uses *Q* = 0 g/s or Ci/s.

CF = units conversion factor of 100 ($mg \cdot m^2/kg \cdot cm^2$) for COPCs. For ROPCs, the conversion factor is 1×10^8 ($pCi \cdot m^2/Ci \cdot cm^2$)

F_v = fraction of constituent air concentration in vapor phase (unitless). F_v is constituent-specific, ranges from 0 to 1. Constituents with a vapor fraction less than 0.05 are modeled as entirely particulate with an F_v value of 0 (CCN 097844). When F_v is not available, it is empirically derived for most constituents (except metals and some mercury compounds) using Eqs. A-2-1 and A-2-2 (when appropriate) in the HHRAP.

Dydv = unitized yearly average dry deposition from vapor phase (s/m²·yr). *Dydv*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dydv* value exists for a constituent, the model uses *Dydv* = 0 s/m²·yr.

Dywv = unitized yearly average wet deposition from vapor phase (s/m²·yr). *Dywv*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dywv* value exists for a constituent, the model uses *Dywv* = 0 s/m²·yr.

Dydp = unitized yearly average dry deposition from particle phase (s/m²·yr). *Dydp*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dydp* value exists for a constituent, the model uses *Dydp* = 0 s/m²·yr.

Dywp = unitized yearly average wet deposition from particle phase (s/m²·yr). *Dywp*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dywp* value exists for a constituent, the model uses *Dywp* = 0 s/m²·yr.

Z_s = soil mixing zone depth (cm). Z_s is site-specific. Three different values (depths) are used for Z_s: untilled soil (2 cm), root-zone soil (15 cm), and tilled soil (20 cm).

BD = soil bulk density (g/cm³). A site-specific value of 1.3 g/cm³ is used (Halvorson et al. 1998).

Equations in Table B-1-1 in the HHRAP are used to calculate the soil deposition term used in soil modeling for total mercury [$Ds_{(Hg)}$], divalent mercury [$Ds_{(Hg^{2+})}$], methyl mercury [$Ds_{(MHg)}$], and elemental mercury [$Ds_{(Hg^0)}$]. $Ds_{(Hg)}$ is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to estimate $Ds_{(Hg)}$ is as follows:

$$Ds_{(Hg)} = \frac{0.48 \cdot Q \cdot CF}{Z_s \cdot BD} \cdot \left[F_{v_{(Hg^{2+})}} \cdot (Dydv + Dywv) + (Dydp + Dywp) \cdot \left(1 - F_{v_{(Hg^{2+})}}\right)\right] \quad \text{(Table B-1-1 in HHRAP)}$$

where:

$Ds_{(Hg)}$ = deposition term to soil for total mercury (mg/kg·yr). $Ds_{(Hg)}$ is constituent-specific, site-specific, and depth-specific.

Q = total mercury emission rate (g/s). *Q*, obtained from calculations after the air dispersion modeling constituent-specific, site-specific and stack-specific.

CF = units conversion factor of 100 (mg·m²/kg·cm²).

$F_{v_{(Hg^{2+})}}$ = fraction of mercury air concentration in vapor phase (unitless). The model uses $F_{v_{(Hg^{2+})}}$ = 0.85 (EPA 2005) for total mercury.

Dydv = unitized yearly average dry deposition from vapor phase (s/m²·yr). *Dydv*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dydv* value exists for a constituent, the model uses *Dydv* = 0 s/m²·yr.

Dywv = unitized yearly average wet deposition from vapor phase (s/m²·yr). *Dywv*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dywv* value exists for a constituent, the model uses *Dywv* = 0 s/m²·yr.

Dydp = unitized yearly average dry deposition from particle phase (s/m²·yr). *Dydp*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dydp* value exists for a constituent, the model uses *Dydp* = 0 s/m²·yr.

Dywp = unitized yearly average wet deposition from particle phase ($s/m^2 \cdot yr$). *Dywp*, from the air dispersion modeling, is site-specific and stack-specific. If no *Dywp* value exists for a constituent, the model uses $Dywp = 0\ s/m^2 \cdot yr$.

Z_s = soil mixing zone depth (cm). Z_s is site-specific. Three different values (depths) are used for Z_s: untilled soil (2 cm), root-zone soil (15 cm), and tilled soil (20 cm).

BD = soil bulk density (g/cm^3). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al. 1998).

A supplemental equation in Table B-1-1 in the HHRAP calculates the soil deposition term used in soil modeling for divalent mercury [$Ds_{(Hg2+)}$]. $Ds_{(Hg2+)}$ is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to estimate $Ds_{(Hg2+)}$ is as follows:

$$Ds_{(Hg^{2+})} = 0.98 \cdot Ds_{(Hg)} \qquad \text{(Table B-1-1 in HHRAP)}$$

where:

$Ds_{(Hg^{2+})}$ = deposition term to soil for divalent mercury ($mg/kg \cdot yr$). $Ds_{(Hg2+)}$ is constituent-specific, site-specific, and depth-specific.

$Ds_{(Hg)}$ = deposition term to soil for total mercury ($mg/kg \cdot yr$). $Ds_{(Hg)}$ is constituent-specific, site-specific, and depth-specific.

A supplemental equation in Table B-1-1 in the HHRAP calculates the soil deposition term used in soil modeling for methyl mercury [$Ds_{(MHg)}$]. $Ds_{(MHg)}$ is used in the estimation of soil concentrations (Eqs. 5-1C, 5-1D, and 5-1E in the HHRAP). The equation to estimate $Ds_{(MHg)}$ is as follows:

$$Ds_{(MHg)} = 0.02 \cdot Ds_{(Hg)} \qquad \text{(Table B-1-1 in HHRAP)}$$

where:

$Ds_{(MHg)}$ = deposition term to soil for methyl mercury ($mg/kg \cdot yr$). $Ds_{(MHg)}$ is constituent-specific, site-specific, and depth-specific.

$Ds_{(Hg)}$ = deposition term to soil for total mercury ($mg/kg \cdot yr$). $Ds_{(Hg)}$ is constituent-specific, site-specific, and depth-specific.

The soil term equation combines the unitized stack deposition rate with the mass flow rate of constituents from the stack and the quantity of soil to arrive at a time-dependent soil concentration.

The time period during which emissions and deposition occur is assumed to start at year zero and cease at year *tD*. Receptor exposures are assumed to occur from year T_1 (when the receptor arrives at the exposure location) to T_2 (when the receptor departs from the exposure location). Receptors that arrive at the exposure location before the cessation of emissions and deposition ($T_1 < tD$) are considered part of the current exposure scenario. Receptors that arrive at the exposure location at the time of, or subsequent to, cessation of emissions and deposition ($T_1 \geq tD$) are considered part of the future exposure scenario.

A.3.2 Soil Concentration

Because the hazard quotient associated with noncarcinogenic constituents is based on a threshold dose rather than a lifetime exposure, the highest annual soil concentration (Cs_{tD}) occurring during the exposure duration period is used for dose assessment for noncarcinogenic constituents. Cs_{tD} typically occurs at the end of the operating life of the emission source. Because carcinogenic risk is averaged over the lifetime of an individual, the soil concentration averaged over the exposure duration (represented by *Cs*) is used for dose assessment for carcinogenic compounds (EPA 2005).

For constituents that undergo soil loss ($ks > 0$), the concentration is increasing due to continued stack deposition during WTP operations, while simultaneously decreasing due to soil loss. After WTP shutdown, constituent accumulation in the soil stops and the loss continues. Since the soil loss is not zero, the soil concentration is a first-order function of the soil deposition term. In instances where there is no soil loss ($ks = 0$), soil concentration is directly proportional to the rate of deposition and time, and reaches a maximum when deposition ceases (at time *tD*). Figure A-1 of this appendix presents the graphical relationship between instantaneous soil concentration, the corresponding running average soil concentration (for a receptor exposed from the time at which emissions and deposition begin), and time. The figure also shows the running soil concentration average for a receptor that arrives at the time at which emissions and deposition end. The figure is based on an emissions/deposition period (*tD*) of 40 yr. Table A-1 of this appendix summarizes the applicable soil concentration equations for the various combinations of carcinogenicity, soil loss, and exposure timing.

Because soil concentrations may require many years to reach steady state, the equations used to calculate the average soil concentration over the period of receptor exposure are derived by integrating the instantaneous soil concentration equation over the period of receptor exposure and dividing by the exposure period (Section 5.2 of HHRAP, EPA 2005). Furthermore, during the time period following the cessation of WTP emissions, soil concentrations decline gradually because of various soil loss mechanisms and may require many more years to reach steady state. Again, integrating the instantaneous soil concentration equation over the period of exposure and dividing by the exposure period will yield an average exposure concentration for the receptor. Because the function for soil concentration changes from accumulation to degradation when emissions cease, exposures before and after WTP shutdown must be distinguished.

The following discussion presents the formulae for the instantaneous soil concentration followed by the derivation of the formulae used to compute average soil concentrations (for use as soil exposure point concentrations [EPCs]).

A.3.2.1 Noncarcinogen Soil Concentration, Current Scenario, No Soil Loss

As stated above, the instantaneous soil concentration for a constituent that does not undergo soil loss is directly proportional to the rate of deposition and time and reaches a maximum when deposition ceases. The instantaneous soil concentration when $ks = 0$ is as follows:

$$Cs_{T2} = Ds \cdot T_2 \qquad \text{(Equation A-1)}$$

where:

Cs_{T2} = instantaneous soil concentration at time T_2 (mg/kg soil).

Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.
T_2	=	the time at the end of exposure (yr), usually set equal to *tD*.

Since the HHRAP stipulates that the highest annual soil concentration (Cs_{tD}) occurring during the exposure duration period is used for dose assessment for noncarcinogenic constituents, the following equation is used to estimate the maximum instantaneous soil concentration for constituents where $ks = 0$ and the receptor is exposed in the current scenario ($T_2 \leq tD$):

$$Cs_{tD} = Ds \cdot tD \qquad \text{(Equation A-2)}$$

where:

Cs_{tD}	=	instantaneous soil concentration at time *tD* (mg/kg soil)
Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.
T_2	=	the time at the end of exposure (yr), usually set equal to *tD*
tD	=	the time at the end of emissions/deposition (yr)

Note that the maximum concentration occurs at time *tD* (at the end of the emissions/deposition period), so the receptor will receive the maximum potential dose when $T_2 \geq tD$, thus, Cs_{tD} is used for the soil EPC of noncarcinogens in the current scenario when there is no soil loss.

A.3.2.2 Carcinogen Soil Concentration, Current Scenario, No Soil Loss

For receptors that are exposed to carcinogens that do not undergo soil losses ($ks = 0$), the average soil concentration is used as the soil EPC. This quantity is determined by integrating the instantaneous soil concentration over the exposure period, and then dividing by the exposure period. For the current scenario where $T_2 \leq tD$ the instantaneous concentration is described by the following equation:

$$Cs_t = Ds \cdot t \qquad \text{(Equation A-3)}$$

where *t* is the time of exposure. Integrating the instantaneous soil concentration over the exposure period and dividing by the exposure period yields the following:

$$\overline{Cs}_{T_1 \to T_2} = \frac{1}{T_2 - T_1} \cdot \int_{T_1}^{T_2} Cs_t dt \to \int_{T_1}^{T_2} Ds \cdot t \; dt \qquad \text{(Equation A-4)}$$

which equates to:

$$\frac{1}{T_2 - T_1} \cdot \left(\frac{Ds \cdot T_2^2}{2} - \frac{Ds \cdot T_1^2}{2} \right)$$

$$\to \quad \left(\frac{Ds}{2} \right) \cdot \left(\frac{1}{T_2 - T_1} \right) \cdot \left[T_2^2 - T_1^2 \right]$$

$$\rightarrow \quad \left(\frac{Ds}{2}\right)\cdot\left(\frac{1}{T_2 - T_1}\right)\cdot\left(T_2 + T_1\right)\cdot\left(T_2 - T_1\right)$$

which simplifies to:

$$\overline{Cs}_{T_1 \rightarrow T_2} = \frac{Ds}{2}\cdot\left(T_2 + T_1\right)$$

where:

$\overline{Cs}_{T_1 \rightarrow T_2}$	=	average soil concentration from time T_1 to T_2 (mg/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific.
T_2	=	the time at the end of exposure (yr), where $T_2 \leq tD$.
T_1	=	the time at the start of exposure (yr).

A.3.2.3 Noncarcinogen Soil Concentration, Current Scenario, With Soil Loss

When a constituent is subject to soil loss, for time $t \leq tD$, there is accumulation of the constituent in the soil from the continued deposition of the constituent; however, there is a simultaneous loss of the constituent at a rate proportional to its value. When a constituent is subject to soil loss, the soil deposition term (Ds) is divided by the soil loss term (ks) to yield the soil concentration. Soil loss is assumed to follow first order kinetics (EPA 2005).

For noncarcinogens evaluated in the current scenario that undergo soil loss, the instantaneous soil concentration is equal to the soil deposition term (Ds) over the soil loss (ks) less any soil loss. The equation describing this is as follows:

$$Cs_t = \frac{Ds}{ks} - \frac{Ds \cdot e^{-ks \cdot t}}{ks} \qquad \text{(Equation A-5)}$$

which is commonly written as:

$$Cs_t = \frac{Ds \cdot \left(1 - e^{-ks \cdot t}\right)}{ks}$$

where:

Cs_t	=	instantaneous soil concentration at time t (mg/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific.
ks	=	overall soil loss constant due to all processes (yr^{-1}).

The maximum concentration occurs at time *tD*, and declines afterwards because of soil loss. Substituting *tD* for *t* in the equation above yields:

$$Cs_{tD} = \frac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks} \qquad \text{(HHRAP Equation 5-1E)}$$

where:

Cs_{tD}	=	instantaneous soil concentration at time *tD* (mg/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.
ks	=	overall soil loss constant due to all processes (yr^{-1}).
tD	=	the time at the end of emissions/deposition (yr).

A.3.2.4 Carcinogen Soil Concentration, Current Scenario, With Soil Loss

Integrating the above equation for Cs_t over the period of T_1 to T_2 (with the constraint $T_1 \le T_2 \le tD$), and dividing by the time period of T_1 to T_2 will yield the average soil exposure concentration for use in estimating carcinogen dose:

$$\overline{Cs}_{T_1 \to T_2} = \frac{1}{T_2 - T_1} \cdot \int_{T_1}^{T_2} Cs_t\, dt \;\rightarrow\; \frac{1}{T_2 - T_1} \cdot \int_{T_1}^{T_2} \frac{Ds \cdot \left(1 - e^{-ks \cdot t}\right)}{ks}\, dt$$

The solution to this integral is:

$$\overline{Cs}_{T_1 \to T_2} = \frac{Ds}{T_2 - T_1} \cdot \left[\left(T_2 \cdot ks \cdot e^{ks \cdot T_2} + 1\right) \cdot \frac{e^{-ks \cdot T_2}}{ks^2} + \left(-T_1 \cdot ks \cdot e^{ks \cdot T_1} - 1\right) \cdot \frac{e^{-ks \cdot T_1}}{ks^2} \right]$$

This equation is simplified by combining terms:

$$\frac{Ds}{T_2 - T_1} \cdot \left[\left(T_2 \cdot ks \cdot e^{ks \cdot T_2} \cdot \frac{e^{-ks \cdot T_2}}{ks^2} + \frac{e^{-ks \cdot T_2}}{ks^2} \right) + \left(-T_1 \cdot ks \cdot e^{ks \cdot T_1} \cdot \frac{e^{-ks \cdot T_1}}{ks^2} - \frac{e^{-ks \cdot T_1}}{ks^2} \right) \right]$$

$$\rightarrow \quad \frac{Ds}{T_2 - T_1} \cdot \left[\left(\frac{T_2}{ks} + \frac{e^{-ks \cdot T_2}}{ks^2} \right) - \left(\frac{T_1}{ks} + \frac{e^{-ks \cdot T_1}}{ks^2} \right) \right]$$

$$\rightarrow \quad \frac{Ds}{ks \cdot \left(T_2 - T_1\right)} \cdot \left[\left(T_2 + \frac{e^{-ks \cdot T_2}}{ks} \right) - \left(T_1 + \frac{e^{-ks \cdot T_1}}{ks} \right) \right]$$

where:

$\overline{Cs}_{T_1 \to T_2}$	=	average soil concentration from time T_1 to T_2 (mg/kg soil).

Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific.
ks	=	overall soil loss constant due to all processes (yr^{-1}).
T_2	=	the time at the end of exposure (yr), where $T_2 \leq tD$.
T_1	=	the time at the start of exposure (yr) , where $T_1 < T_2$.

If T_2 is set to tD, then the solution becomes:

$$\overline{Cs}_{tD} = \frac{Ds}{ks \cdot (tD - T_1)} \cdot \left[\left(tD + \frac{e^{-ks \cdot tD}}{ks} \right) - \left(T_1 + \frac{e^{-ks \cdot T_1}}{ks} \right) \right] \qquad \text{(HHRAP Equation 5-1C)}$$

where:

$\overline{Cs}_{tD}$	=	average soil concentration at time tD (mg/kg soil)
Cs_{T2}	=	instantaneous soil concentration at time T_2 (mg/kg soil)
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific
ks	=	overall soil loss constant due to all processes (yr^{-1})
tD	=	the time at the end of emissions/deposition (yr)

A.3.2.5 Noncarcinogen Soil Concentration, Future Scenario, No Soil Loss

Since there is no loss, the contaminant level is assumed to remain constant subsequent to cessation of emissions, therefore, Cs_{tD} is used for the soil EPC of noncarcinogens in the future scenario when there is no soil loss.

$$Cs_{T2} = Cs_{tD} = Ds \cdot tD \qquad \text{(Equation A-6)}$$

where:

Cs_{T2}	=	instantaneous soil concentration at time T_2 (mg/kg soil).
Cs_{tD}	=	instantaneous soil concentration at time tD, or subsequent to time tD (mg COPC/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific.
tD	=	the time at the end of emissions/deposition (yr).

A.3.2.6 Carcinogen Soil Concentration, Future Scenario, No Soil Loss

The maximum concentration occurs at time tD, and since there is no soil loss or continued emissions, the corresponding average concentration cannot exceed the level it reaches at time tD, thus, Cs_{tD} is used for future scenarios:

$$\overline{Cs}_{tD \to T_2} = \frac{1}{T_2 - tD} \cdot \int_{tD}^{T_2} Cs_{tD} \; dt \qquad \text{(Equation A-7)}$$

$$\rightarrow \quad \overline{Cs}_{tD \to T_2} = \frac{1}{T_2 - tD} \cdot \int_{tD}^{T_2} Ds \cdot t \; dt \qquad \text{(Equation A-8)}$$

the solution to this integral is:

$$\frac{Ds}{T_2 - tD} \cdot \left(\frac{T_2^{\,2} - tD^2}{2} \right) \qquad \text{(Equation A-9)}$$

$$\rightarrow \quad \frac{Ds}{2} \cdot \left(T_2 + tD \right) \qquad \text{(Equation A-10)}$$

where:

$\overline{Cs}_{tD \to T_2}$	=	average soil concentration from time tD to T_2 (mg/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.
T_2	=	the time at the end of exposure (yr), where $tD \le T_2$.
tD	=	the time at the end of emissions/deposition (yr).

A.3.2.7 Noncarcinogen Soil Concentration, Future Scenario, With Soil Loss

For noncarcinogens evaluated in the future scenario that undergo soil loss, the instantaneous soil concentration is equal to the soil concentration at the time emissions/deposition ceased, less any decline in soil concentration due to losses. At time tD (time emissions/deposition ceased), the soil concentration is as follows:

$$Cs_{tD} = \frac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks} \qquad \text{(HHRAP Equation 5-1E)}$$

and at some time in the future, T_2, the remaining concentration (with the constraint of $tD \le T_2$) is:

$$Cs_{T2} = Cs_{tD} \cdot e^{-ks \cdot (T_2 - tD)} \qquad \text{(Equation A-11)}$$

However, since noncarcinogenic risk is based on a threshold value (the reference dose), HHRAP (Section 5.2.1) recommends that the maximum instantaneous concentration should be used for risk assessment. Therefore, the following equation applies:

$$Cs_{T2} = Cs_{tD} = \frac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks} \qquad \text{(Equation A-12)}$$

where:

Cs_{T2}	=	instantaneous soil concentration at time T_2 (mg/kg soil).
Cs_{tD}	=	soil concentration at time *tD* (mg COPC/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.
ks	=	overall soil loss constant due to all processes (yr^{-1}).
tD	=	the time at the end of emissions/deposition (yr).
T_2	=	the time at the end of exposure (yr), where $tD \leq T_2$.

The maximum concentration occurs at time *tD* and declines afterwards because of soil loss.

A.3.2.8 Carcinogen Soil Concentration, Future Scenario, With Soil Loss

Integrating the above equation for *Cs* over the period of *tD* to T_2 (with the constraint $tD \leq T_2$), and dividing by the time period of *tD* to T_2 will yield the average soil exposure concentration for use in estimating carcinogen dose.

$$\overline{Cs}_{tD\to T_2} = \frac{1}{T_2 - tD} \cdot \int_{tD}^{T_2} Cs_{tD} \cdot e^{-ks\cdot(t-tD)} dt \qquad \text{(Equation A-13)}$$

$$\to \quad \frac{Cs_{tD}}{T_2 - tD} \cdot \int_{tD}^{T_2} e^{-ks\cdot(t-tD)} dt$$

the solution to this integral is:

$$\frac{Cs_{tD}}{T_2 - tD} \cdot \left(\frac{1}{ks} + \frac{-e^{-ks\cdot(T_2 - tD)}}{ks} \right)$$

this equation is simplified by combining terms:

$$\frac{Cs_{tD}}{ks \cdot (T_2 - tD)} \cdot \left(1 - e^{-ks\cdot(T_2 - tD)}\right)$$

where:

$\overline{Cs}_{tD\to T_2}$	=	average soil concentration from time *tD* to T_2 (mg/kg soil)
Cs_{tD}	=	instantaneous soil concentration at time *tD* ($Cs_{tD} = Ds\cdot(1-e^{-ks\cdot tD})/ks$), (mg/kg soil)
tD	=	the time at the end of emissions/deposition (yr)
T_2	=	the time at the end of exposure (yr), where $tD \leq T_2$.
Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.
ks	=	overall soil loss constant due to all processes (yr^{-1})

To compute the average soil concentration for exposure over a distinct time interval (from time T_1 to T_2), integrate of the timeframe of interest, and divide by the time.

$$\overline{Cs}_{T_1 \to T_2} = \frac{1}{T_2 - T_1} \cdot \int_{T_1}^{T_2} Cs_{tD} \cdot e^{-ks \cdot (t - tD)} dt \qquad \text{(Equation A-14)}$$

this equation equates to:

$$\frac{Cs_{tD}}{T_2 - T_1} \cdot \left(\int_{tD}^{T_2} e^{-ks \cdot (t - tD)} dt - \int_{tD}^{T_1} e^{-ks \cdot (t - tD)} dt \right)$$

which yields:

$$\frac{Cs_{tD}}{ks \cdot (T_2 - T_1)} \cdot \left(e^{-ks \cdot (T_1 - tD)} - e^{-ks \cdot (T_2 - tD)} \right)$$

where:

$\overline{Cs}_{T_1 \to T_2}$	=	average soil concentration from time T_1 to T_2 (mg/kg soil)
Cs_{tD}	=	instantaneous soil concentration at time tD ($Cs_{tD} = Ds \cdot (1 - e^{-ks \cdot tD})/ks$), (mg/kg soil)
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific
ks	=	overall soil loss constant due to all processes (yr^{-1})
tD	=	the time at the end of emissions/deposition (yr)
T_2	=	the time at the end of exposure (yr), where $tD < T_2$
T_1	=	the time at the start of exposure (yr), where $tD \leq T_1 < T_2$

A.3.2.9 Noncarcinogen Soil Concentration, Spanning Current and Future Scenarios, With No Soil Loss

Some receptors may have an exposure duration that exceeds the period on emissions/deposition. In such cases, both current and future scenario equations must be combined. For constituents that do not undergo soil loss, the contaminant level increases throughout the emissions period, and is assumed to remain constant subsequent to cessation of emissions. Accordingly, instantaneous soil concentration is computed as follows:

$$Cs_{T2} = Ds \cdot tD \qquad \text{(Equation A-15)}$$

where:

Cs_{T2}	=	instantaneous soil concentration at time T_2 (mg/kg soil)
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific
tD	=	the time at the end of emissions/deposition (yr)

A.3.2.10 Carcinogen Soil Concentration, Spanning Current and Future Scenarios, With No Soil Loss

For a receptor whose exposure time spans the period of emissions and a time period after cessation of emissions, the equation for the average soil concentration must also include the contribution of post-emissions/deposition exposure with exposure during emissions/deposition:

$$\overline{Cs}_{T_2 \to T_1} = \frac{1}{T_2 - T_1} \cdot \left(\int_{T_1}^{tD} Cs_t dt + \int_{tD}^{T_2} Cs_t dt \right) \qquad \text{(Equation A-16)}$$

which equates to:

$$\frac{1}{T_2 - T_1} \cdot \left(\int_{T_1}^{tD} Ds \cdot t \ dt + \int_{tD}^{T_2} Cs_{tD} dt \right)$$

which yields:

$$\frac{1}{T_2 - T_1} \cdot \left[\frac{Ds \cdot tD}{2} \cdot (T_2 - tD) + \frac{Ds}{2} \cdot \left(tD^2 - T_1^2 \right) \right]$$

$$\rightarrow \qquad \frac{Ds}{2 \cdot (T_2 - T_1)} \cdot \left(T_2 \cdot tD - T_1^2 \right)$$

where:

$\overline{Cs}_{T_1 \to T_2}$	=	average soil concentration from time T_1 to T_2 (mg/kg soil)
Ds	=	deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific
T_2	=	the time at the end of exposure (yr), where $T_2 \geq tD$.
T_1	=	the time at the start of exposure (yr), where $T_1 < tD$
tD	=	the time at the end of emissions/deposition (yr)

A.3.2.11 Noncarcinogen Soil Concentration, Spanning Current and Future Scenarios, With Soil Loss

For noncarcinogens that span the current and future scenario and undergo soil loss, the instantaneous soil concentration is equal to the soil concentration at the time emissions/deposition ceased, less any decline in soil concentration due to losses. At time *tD* (time emissions/deposition ceased), the soil concentration is as follows:

$$Cs_{tD} = \frac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks} \qquad \text{(HHRAP Equation 5-1E)}$$

and at some time in the future, T_2, the remaining concentration (with the constraint of $tD \leq T_2$) is:

$$Cs_{T2} = Cs_{tD} \cdot e^{-ks \cdot (T_2 - tD)} \qquad \text{(Equation A-17)}$$

However, since noncarcinogenic risk is based on a threshold value (the reference dose), HHRAP (Section 5.2.1) recommends that the maximum instantaneous concentration should be used for risk assessment. Therefore, the following equation applies:

$$Cs_{T2} = Cs_{tD} = \frac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks} \qquad \text{(Equation A-18)}$$

where:

Cs_{T2}	=	instantaneous soil concentration at time T_2 (mg/kg soil).
Cs_{tD}	=	soil concentration at time tD (mg COPC/kg soil).
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific.
ks	=	overall soil loss constant due to all processes (yr^{-1}).
tD	=	the time at the end of emissions/deposition (yr).
T_2	=	the time at the end of exposure (yr), where $tD \leq T_2$.

A.3.2.12 Carcinogen Soil Concentration, Spanning Current and Future Scenarios, With Soil Loss

Accounting for the contribution of post-emissions/deposition exposure (Section A.3.2.4) with exposure during emissions/deposition (Section A.3.2.8), the following integral is used to derive the average soil concentration:

$$\overline{Cs}_{T_1 \to T_2} = \frac{1}{T_2 - T_1} \cdot \left(\int_{T_1}^{tD} Cs_t \, dt + \int_{tD}^{T_2} Cs_{tD} \cdot e^{-ks \cdot (t - tD)} dt \right) \qquad \text{(Equation A-19)}$$

which equates to:

$$\frac{1}{T_2 - T_1} \cdot \left(\int_{T_1}^{tD} \frac{Ds \cdot \left(1 - e^{-ks \cdot t}\right)}{ks} dt + Cs_{tD} \cdot \int_{tD}^{T_2} e^{-ks \cdot (t - tD)} dt \right)$$

the solution to this integral is:

$$\frac{1}{T_2 - T_1} \cdot \left[\frac{Ds}{ks} \cdot \left[\left(tD + \frac{e^{-ks \cdot tD}}{ks} \right) - \left(T_1 + \frac{e^{-ks \cdot T_1}}{ks} \right) \right] + \frac{Cs_{tD}}{ks} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

this equation is simplified by combining and canceling terms:

$$\frac{1}{T_2 - T_1} \cdot \left[\left(\frac{Ds \cdot tD}{ks} + \frac{Ds \cdot e^{-ks \cdot tD}}{ks^2} \right) - \left(\frac{Ds \cdot T_1}{ks} + \frac{Ds \cdot e^{-ks \cdot T_1}}{ks^2} \right) + \frac{Cs_{tD}}{ks} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

$$\rightarrow \quad \frac{1}{T_2 - T_1} \cdot \left[\frac{Ds \cdot tD - Ds \cdot T_1}{ks} + \frac{Ds \cdot e^{-ks \cdot tD} - Ds \cdot e^{-ks \cdot T_1}}{ks^2} + \frac{Cs_{tD}}{ks} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

$$\rightarrow \quad \frac{Ds}{ks \cdot (T_2 - T_1)} \cdot \left[tD - T_1 + \frac{e^{-ks \cdot tD} - e^{-ks \cdot T_1}}{ks} + \frac{Cs_{tD}}{Ds} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

where:

$\overline{Cs}_{T_1 \rightarrow T_2}$	=	average soil concentration from time T_1 to T_2 (mg/kg soil)
Cs_{tD}	=	instantaneous soil concentration at time tD ($Cs_{tD} = Ds \cdot (1-e^{-ks \cdot tD})/ks$), (mg/kg soil)
Ds	=	deposition term to soil (mg/kg·yr). Ds is constituent-specific, site-specific, and depth-specific
T_2	=	the time at the end of exposure (yr), where $T_2 > tD$
T_1	=	the time at the start of exposure (yr), where $T_1 < tD$
tD	=	the time at the end of emissions/deposition (yr)

Note that if T_1 is set to coincide with the start of emissions/deposition ($T_1 = 0$) as assumed in the HHRAP, then the equation above can be simplified as follows:

$$\frac{Ds}{ks \cdot (T_2 - T_1)} \cdot \left[tD - 0 + \frac{e^{-ks \cdot tD} - 1}{ks} + \frac{Cs_{tD}}{Ds} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

$$\rightarrow \quad \frac{1}{T_2 - T_1} \cdot \left[\frac{Ds \cdot tD}{ks} + \frac{Ds \cdot \left(e^{-ks \cdot tD} - 1\right)}{ks^2} + \frac{Cs_{tD}}{ks} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

$$\rightarrow \quad \frac{1}{T_2 - T_1} \cdot \left[\frac{Ds \cdot tD}{ks} + \frac{-Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks} \cdot \frac{1}{ks} + \frac{Cs_{tD}}{ks} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

and substituting $Cs_{tD} = \dfrac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks}$

$$\rightarrow \quad \frac{1}{T_2 - T_1} \cdot \left[\frac{Ds \cdot tD}{ks} + \frac{-Cs_{tD}}{ks} + \frac{Cs_{tD}}{ks} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right) \right]$$

$$\rightarrow \quad \frac{\dfrac{Ds \cdot tD - Cs_{tD}}{ks} + \left(\dfrac{Cs_{tD}}{ks}\right) \cdot \left(1 - e^{-ks \cdot (T_2 - tD)}\right)}{T_2 - T_1} \qquad \text{(HHRAP Equation 5-1D)}$$

Figure A-1 shows a plot of soil concentration (*Cs*) with time (*T*) for the various equations above. The plot lines represent the change in exposure point concentration as it might correspond with a given exposure duration as represented by the light blue bars. The bars represent the receptor's exposure on the timeline of WTP operations and post-operations (current and future exposure scenarios). The bars help illustrate how receptor exposure scenarios have been developed to conservatively coincide maximum exposures.

The blue line shows the instantaneous soil concentration with time for cases where there is no known soil loss ($Cs = Ds \cdot T$, $ks = 0$). The magenta line below shows an average soil concentration, without soil loss, that is, it represents the area under the blue line, divided by time ($Cs = Ds \cdot T \div 2$, $ks = 0 Cs = (Ds \cdot T) \div 2, ks = 0$). In both cases, at the end of operations (*tD*), the soil concentration has reached a maximum, Cs_{tD} ($Cs_{tD} = Ds \cdot tD$ and $Cs_{tD} = Ds \cdot tD \div 2 Cs_{tD} = (Ds \cdot tD) \div 2$, respectively) since this is when deposition of emitted particles ceases.

The green line shows the instantaneous soil concentration with soil loss ($Cs = (Ds/ks) \cdot [1-e^{-ks \cdot T}]$, $ks \neq 0$). At time *tD* soil concentration has reached its maximum, Cs_{tD} ($Cs_{tD} = (Ds/ks) \cdot [1-e^{-ks \cdot tD}] Cs_{tD} = \frac{Ds}{ks} \cdot [1 - e^{-ks \cdot tD}]$), when operations cease and deposition is no longer occurring, at which point the soil concentration begins decreasing due to losses ($Cs = [Cs_{tD}/(ks \cdot (T-tD)] \cdot [1-e^{-ks \cdot (T-tD)}]$).

The red line represents average soil concentration, with time and soil loss ($Cs = [Ds/(ks \cdot T)] \cdot (T+[e^{-ks \cdot T}-1]/ks)$, $ks \neq 0$). Because the line plots the average concentration, the line represents the area under the green instantaneous soil concentration line, divided by time. As with other plots of soil concentration, the maximum, Cs_{tD} ($Cs_{tD} = Ds \cdot [1-e^{-ks \cdot tD}]/ks$)$Cs_{tD} = Ds \cdot [1 - e^{-ks \cdot tD}]/ks$, is reached at the cessation of WTP operations. The plot shows that as a receptor remains exposed, the average EPC declines as soil loss occurs ($Cs = [(Ds \cdot tD - Cs_{tD})/(ks \cdot T)] + [Cs_{tD}/(ks \cdot T)] \cdot [1-e^{-ks \cdot (T-tD)}]$).

The figure shows that for current scenarios, the EPC is conservatively computed assuming exposure concludes at time = *tD* for any case where the exposure duration (*ED*) is less than 40 years, thus the corresponding soil EPC is Cs_{tD}. For current exposure scenarios where the exposure duration (*ED*) is greater than 40 years, the figure shows the value of Cs_{tD} is used as the EPC for assessing exposures where there is no known soil loss. In cases where there is soil loss, noncarcinogen exposures are bounded at EPC = Cs_{tD}, however, carcinogen exposures (where an average soil concentration is used), the EPC declines after the cessation of emissions due to the effect of soil loss. The figure also shows the start of receptor exposure is set to coincide with time = *tD* in the future scenarios. Future exposures are also bounding because the EPC is *CstD* when the soil loss is zero or unknown. When there are soil losses, receptor exposure occurs over the period of highest concentration as opposed to the tail end of the assessment period when soil concentrations are tapering off. As an example, the figure shows where (on the plotted lines) the exposure concentrations correspond with an *ED* = 70 yr for a current exposure scenario spanning plant operations, and *ED* = 30 yr and *ED* = 40 yr for a future exposure scenario.

A.4 Water Body Load

A.4.1 Direct Deposition Load to Water Body (L_{DEP})

Equation 5-29 (Table B-4-8) in the HHRAP calculates the average load to the water body from direct deposition of wet and dry particles and wet and dry vapors onto the surface of the water body (L_{DEP}) for all constituents (ROPCs and COPCs), except divalent mercury and methyl mercury. L_{DEP} is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate L_{DEP} is:

$$L_{DEP} = Q \cdot \left[F_v \cdot Dytwv + (1 - F_v) \cdot Dytwp\right] \cdot A_w \qquad \text{(Eq. 5-29 in HHRAP)}$$

where:

L_{DEP}	=	total (wet and dry) particle-phase and total (wet and dry) vapor-phase direct deposition load to water body (g/yr for COPCs and Ci/yr for ROPCs). L_{DEP} is constituent-specific and site-specific.
Q	=	constituent-specific emission rate (g/s for COPCs and Ci/s for ROPCs). Q, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific, and stack-specific. If no value exists for Q, a value of 0 g/s (for COPCs) or 0 Ci/s (for ROPCs) is used.
F_v	=	fraction of constituent air concentration in vapor phase (unitless). F_v is constituent-specific, ranges from 0 to 1. Constituents with a vapor fraction less than 0.05 are modeled as entirely particulate with an F_v value of 0 (CCN 097844). When F_v is not available, it is empirically derived for most constituents (except metals and some mercury compounds) using (when appropriate) Eqs. A-2-1 and A-2-2 in the HHRAP. In accordance with the HHRAP, the F_v of metals is assumed to be zero.
$Dytwv$	=	unitized yearly average wet deposition from vapor phase over water body (s/m²·yr). $Dytwv$, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of $Dywv$ and $Dydv$. $Dytwv = Dywv + Dydv$ — $Dywv$ and $Dydv$ are defined in A.3.1 If no $Dytwv$ value exists for a constituent, the model uses $Dytwv = 0$ s/m²·yr.
$Dytwp$	=	unitized yearly average total (wet and dry) deposition from particle phase over water body (s/m²·yr). $Dytwp$, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of $Dywp$ and $Dydp$. $Dytwp = Dywp + Dydp$ — $Dywp$ and $Dydp$ are defined in A.3.1 If no $Dytwp$ value exists for a constituent, the model uses $Dytwp = 0$ s/m²·yr.
A_w	=	average annual water body surface area (m²). A_w is site-specific, a value of $A_w = 3.652E+07$ m² is used (PNNL 2005b).

Table B-4-8 in the HHRAP also contains the equation to calculate the average load to the water body from direct deposition of wet and dry particles and wet and dry vapors onto the surface of the water body for total mercury [$L_{DEP(Hg)}$]. $L_{DEP(Hg)}$ is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate $L_{DEP(Hg)}$ is:

$$L_{DEP_{(Hg)}} = 0.48 \cdot Q_{(Hg)} \cdot \left[F_{v(Hg^{2+})} \cdot Dytwv + (1 - F_{v(Hg^{2+})}) \cdot Dytwp\right] \cdot A_w \qquad \text{(Table B-4-8 in HHRAP)}$$

where:

$L_{DEP(Hg)}$ = total (wet and dry) particle phase and total (wet and dry) vapor phase direct deposition load to water body for total mercury (g/yr). $L_{DEP(Hg)}$ is constituent-specific and site-specific.

$Q_{(Hg)}$ = COPC-specific emission rate for total mercury (g/s). $Q_{(Hg)}$, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific and stack-specific.

$F_{v_{(Hg^{2+})}}$ = fraction of mercury air concentration in vapor phase (unitless). The model uses $F_{v_{(Hg^{2+})}}$ = 0.85 (refer to Table B-4-8 in the HHRAP) for total mercury.

Dytwv = unitized yearly average wet deposition from vapor phase over water body (s/m^2·yr). *Dytwv*, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of *Dywv* and *Dydv*.

$Dytwv = Dywv + Dydv$ *Dywv* and *Dydv* are defined in A.3.1

If no *Dytwv* value exists for a constituent, the model uses *Dytwv* = 0 s/m^2·yr.

Dytwp = unitized yearly average total (wet and dry) deposition from particle phase over water body (s/m^2·yr). *Dytwp*, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of *Dywp* and *Dydp*.

$Dytwp = Dywp + Dydp$ *Dywp* and *Dydp* are defined in A.3.1

If no *Dytwp* value exists for a constituent, the model uses *Dytwp* = 0 s/m^2·yr.

A_w = average annual water body surface area (m^2). A_w is site-specific, a value of A_w = 3.652E+07 m^2 is used (PNNL 2005b).

A.4.2 Diffusion Load to Water Body (L_{dif})

Equation 5-30 (Table B-4-12) in the HHRAP calculates the load to the water body due to dry vapor diffusion (L_{dif}) for all constituents except divalent mercury and methyl mercury. L_{dif} is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate L_{dif} is:

$$L_{dif} = \frac{K_v \cdot Q \cdot F_v \cdot Cywv \cdot A_w \cdot CF}{\frac{H}{R \cdot T_{wk}}}$$ (Eq. 5-30 in HHRAP)

where:

L_{dif} = vapor phase COPC or ROPC dry deposition diffusion load to water body (g/yr for COPCs and Ci/yr for ROPCs). L_{dif} is constituent-specific and site-specific.

K_v = overall transfer rate coefficient (m/yr). K_v is constituent-specific, site-specific, and is calculated in Eq. 5-40 in the HHRAP.

Q = constituent-specific emission rate (g/s for COPCs and Ci/s for ROPCs). Q, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific, and stack-specific. If no value exists for Q, a value of 0 g/s (for COPCs) or 0 Ci/s (for ROPCs) is used.

F_v = fraction of constituent air concentration in vapor phase (unitless). F_v is constituent-specific, ranges from 0 to 1. Constituents with a vapor fraction less than 0.05 are modeled as entirely particulate with an F_v value of 0 (CCN 097844). When F_v is not available, it is empirically derived for most constituents (except metals and some mercury compounds) using (when appropriate) Eqs. A-2-1 and A-2-2 in the HHRAP. In accordance with the HHRAP, the F_v of metals is assumed to be zero.

$Cywv$ = unitized yearly average air concentration from vapor phase over the water body (µg·s/g·m^3 for COPCs and µCi·s/Ci·m^3 for ROPCs). $Cywv$, from the air dispersion modeling, is site-specific and stack-specific. $Cywv$ is the same as Cyv , the unitized yearly air concentration from vapor phase. If no value exists for $Cywv$, the model uses $Cywv$ = 0 µg·s/g·m^3 for COPCs and $Cywv$ = 0 µCi·s/Ci·m^3 for ROPCs.

A_w = average annual water body surface area (m^2). A_w is site-specific, a value of A_w = 3.652E+07 m^2 is used (PNNL 2005b).

CF = units conversion factor of 1×10^{-6} (g/µg for COPCs and Ci/µCi for ROPCs)

H = Henry's Law Constant (atm·m^3/mol). H is constituent-specific. If no value is available for H, then it is estimated using Eq. A-2-3 in the HHRAP if constituent vapor pressure and water solubility data are available, otherwise, the model uses L_{dif} = 0 g/yr for COPCs and Ci/yr for ROPCs.

R = universal gas constant (atm·m^3/mol-°K). A value of $R = 8.205 \times 10^{-5}$ atm·m^3/mol·°K is used.

T_{wk} = water body temperature (°K). T_{wk} is site-specific and an average value of 285 °K is used (PNNL 2003. 2004, 2005a, 2006, 2007).

Table B-4-12 in the HHRAP also provides an equation to calculate the load to the water body due to dry vapor diffusion for total mercury [$L_{dif(Hg)}$]. $L_{dif(Hg)}$ is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate $L_{dif(Hg)}$ is:

$$L_{dif(Hg)} = \frac{K_v \cdot 0.48 \cdot Q_{(Hg)} \cdot F_{v_{(Hg^{2+})}} \cdot Cywv \cdot A_w \cdot CF}{\dfrac{H}{R \cdot T_{wk}}} \qquad \text{(Table B-4-12 in HHRAP)}$$

where:

$L_{dif(Hg)}$ = vapor phase COPC dry deposition diffusion load to water body for total mercury (g/yr). $L_{dif(Hg)}$ is constituent-specific and site-specific.

K_v = overall transfer rate coefficient for total mercury (m/yr). K_v is constituent-specific, site-specific, and is calculated in Eq. 5-40 in the HHRAP.

$Q_{(Hg)}$ = constituent-specific emission rate for total mercury (g/s). $Q_{(Hg)}$, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific, and stack-specific.

$F_{v_{(Hg^{2+})}}$ = fraction of mercury air concentration in vapor phase (unitless). The model uses $F_{v_{(Hg^{2+})}}$ = 0.85 (refer to Table B-4-12 in the HHRAP) for total mercury.

$Cywv$ = unitized yearly average air concentration from vapor phase over the water body (µgs/g·m^3). $Cywv$, from the air dispersion modeling, is site-specific and stack-specific. $Cywv$ is the same as Cyv , the unitized yearly air concentration from vapor phase.

A_w = average annual water body surface area (m^2). A_w is site-specific, a value of A_w = 3.652E+07 m^2 is used (PNNL 2005b).

CF	=	units conversion factor of 1×10^{-6} (g/µg)
H	=	Henry's Law Constant for total mercury (atm·m^3/mol).
R	=	universal gas constant (atm·m^3/mol-°K). A value of $R = 8.205 \times 10^{-5}$ atm·m^3/mol-°K is used.
T_{wk}	=	water body temperature (°K). T_{wk} is site-specific and an average value of 285 °K is used (PNNL 2003. 2004, 2005a, 2006, 2007).

A.4.3 Runoff Load From Impervious Surfaces (L_{RI})

Equation 5-31 (Table B-4-9) in the HHRAP calculates the average runoff load to the water body from impervious surfaces in the watershed from which runoff is conveyed directly to the water body (L_{RI}), for all constituents except total mercury. L_{RI} is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate L_{RI} is:

$$L_{RI} = Q \cdot \left[F_v \cdot Dytwv + \left(1 - F_v\right) \cdot Dytwp\right] \cdot A_I \qquad \text{(Eq. 5-31 in HHRAP)}$$

where:

L_{RI}	=	runoff load from impervious surfaces (g/yr for COPCs and Ci/yr for ROPCs). L_{RI} is constituent-specific and site-specific.
Q	=	COPC or ROPC-specific emission rate (g/s for COPCs and Ci/s for ROPCs). Q, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific, and stack-specific. If no value exists for Q, a value of 0 g/s (for COPCs) or 0 Ci/s (for ROPCs) is used.
F_v	=	fraction of constituent air concentration in vapor phase (unitless). F_v is constituent-specific, ranges from 0 to 1. Constituents with a vapor fraction less than 0.05 are modeled as entirely particulate with an F_v value of 0 (CCN 097844). When F_v is not available, it is empirically derived for most constituents (except metals and some mercury compounds) using (when appropriate) Eqs. A-2-1 and A-2-2 in the HHRAP. In accordance with the HHRAP, the F_v of metals is assumed to be zero.
$Dytwv$	=	unitized yearly average wet deposition from vapor phase over water body (s/m^2·yr). $Dytwv$, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of $Dywv$ and $Dydv$. $Dytwv = Dywv + Dydv$ $Dywv$ and $Dydv$ are defined in A.3.1 If no $Dytwv$ value exists for a constituent, the model uses $Dytwv$ = 0 s/m^2·yr.
$Dytwp$	=	unitized yearly average total (wet and dry) deposition from particle phase over water body (s/m^2·yr). $Dytwp$, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of $Dywp$ and $Dydp$. $Dytwp = Dywp + Dydp$ $Dywp$ and $Dydp$ are defined in A.3.1 If no $Dytwp$ value exists for a constituent, the model uses $Dytwp$ = 0 s/m^2·yr.
A_I	=	impervious watershed area receiving COPC deposition (m^2). A_I is site-specific. The model uses A_I = 0 m^2.

Table B-4-9 in the HHRAP also calculates the average runoff load to the water body from impervious surfaces in the watershed from which runoff is conveyed directly to the water body, for total mercury

[$L_{RI(Hg)}$]. $L_{RI(Hg)}$ is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate $L_{RI(Hg)}$ is:

$$L_{RI(Hg)} = 0.48 \cdot Q_{(Hg)} \cdot \left[F_{v(Hg^{2+})} \cdot Dywwv + (1 - F_{v(Hg^{2+})}) \cdot Dytwp \right] \cdot A_I \qquad \text{(Table B-4-9 in HHRAP)}$$

where:

$L_{RI(Hg)}$	=	runoff load from impervious surfaces for total mercury (g/yr). $L_{RI(Hg)}$ is constituent-specific and site-specific.
$Q_{(Hg)}$	=	constituent-specific emission rate for total mercury (g/s). $Q_{(Hg)}$, obtained from calculations after the air dispersion modeling, is constituent-specific, site-specific and stack-specific.
$F_{v(Hg^{2+})}$	=	fraction of mercury air concentration in vapor phase (unitless). The model uses $F_{v(Hg^{2+})} = 0.85$ (refer to Table B-4-9 in the HHRAP) for total mercury.
Dytwv	=	unitized yearly average wet deposition from vapor phase over water body (s/m^2·yr). *Dytwv*, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of *Dywv* and *Dydv*. *Dytwv* = *Dywv* + *Dydv* *Dywv* and *Dydv* are defined in A.3.1 If no *Dytwv* value exists for a constituent, the model uses *Dytwv* = 0 s/m^2·yr.
Dytwp	=	unitized yearly average total (wet and dry) deposition from particle phase over water body (s/m^2·yr). *Dytwp*, from the air dispersion modeling, is site-specific and stack-specific, and is the sum of *Dywp* and *Dydp*. *Dytwp* = *Dywp* + *Dydp* *Dywp* and *Dydp* are defined in A.3.1 If no *Dytwp* value exists for a constituent, the model uses *Dytwp* = 0 s/m^2·yr.
A_I	=	impervious watershed area receiving COPC or ROPC deposition (m^2). A_I is site-specific. The model uses $A_I = 0$ m^2.

Since evapotranspiration exceeds precipitation in the Hanford Site area (e.g., there is no water to run off; the water goes back up into the air) there is insufficient water available to cause significant runoff of COPCs and ROPCs, thus surface runoff is expected to be an insignificant soil loss mechanism and an insignificant surface water loading mechanism (refer to Section 6.3). The model therefore sets L_{RI} equal to zero for all constituents.

A.4.4 Pervious Runoff Load to Water Body (L_R)

Equation 5-32 (Table B-4-10) in the HHRAP calculates the average runoff load to the water body from pervious soil surfaces in the watershed (L_R) for all COPCs. Note that the untilled soil concentration is used in this equation. L_R is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate L_R for COPCs (Eq. 5-32 in EPA 2005) is:

$$L_{RP} = RO \cdot (A_L - A_I) \cdot \left(\frac{Cs_2 \cdot BD}{\theta_{sw} + Kd_s \cdot BD} \right) \cdot CF \qquad \text{(Equation 5-32 in HHRAP)}$$

where:

L_{RP} = runoff load from pervious surfaces (g/yr). L_{RP} is constituent-specific and site-specific.

RO = average annual surface runoff from pervious areas (cm/yr). RO is site-specific. A value of 2.5 cm/yr is used (estimated value, assuming that the majority of rainfall recharges or evaporates).

A_L = total watershed area receiving COPC deposition (m^2). A_L is site-specific. The model uses $A_L = 3.927 \times 10^9\ m^2$ (estimated as half of the study area).

A_I = impervious watershed area receiving COPC deposition (m^2). A_I is site-specific. The model uses $A_I = 0\ m^2$.

Cs_2 = constituent concentration over the exposure duration in untilled soil (mg/kg). Cs_2 is constituent-specific, site-specific, and is calculated using Eqs. 5-1C, 5-1D, and 5-1E of the HHRAP.

BD = soil bulk density (g soil/cm^3 soil). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al. 1998).

CF = units conversion factor of 0.01 (kg·cm^2/mg·m^2) for COPCs, and 1×10^{-8} (Ci·cm^2/pCi·m^2) for ROPCs.

θ_{sw} = soil volumetric water content (mL water/cm^3 soil). θ_{sw} is site-specific. The EPA-recommended default value of 0.2 mL/cm^3 is used (Eq. 5-32 in HHRAP).

Kd_s = soil-water partition coefficient (mL/g). Kd_s is constituent-specific. If no Kd_s value exists for an organic constituent, then Kd_s is estimated using Eq. A-2-10 in the HHRAP and a $f_{oc} = 0.0044$ (fraction of organic carbon in soil, site-specific value from average organic carbon measurements [CCN 150854]), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_s is not available and cannot be estimated, the model uses $Kd_s = 0$ mL/g.

Since evapotranspiration exceeds precipitation in the Hanford Site area (there is no water to run off; the water goes back up into the air) there is insufficient water available to cause significant runoff of COPCs and ROPCs, thus surface runoff is expected to be an insignificant soil loss mechanism and an insignificant surface water loading mechanism (refer to Section 6.3). The model therefore sets L_{RP} equal to zero for all constituents.

A.4.5 Soil Erosion Load (L_E)

Equation 5-33 (Table B-4-11) in the HHRAP calculates the average load to the water body from soil erosion (L_E). Since one of the parameters in the equation (ER) is not defined for ROPCs, L_E is only quantified for COPCs. Note that the untilled soil concentration is used in this equation. L_E is used in the estimation of the total load to the surface water body (see Eq. 5-28 in the HHRAP). The equation to estimate L_E for all COPCs (Eq. 5-33 in the HHRAP) is:

$$L_E = X_e \cdot (A_L - A_I) \cdot SD \cdot ER \cdot \left(\frac{Cs_2 \cdot Kd_s \cdot BD}{\theta_{sw} + Kd_s \cdot BD} \right) \cdot CF \qquad \text{(Eq. 5-33 in HHRAP)}$$

where:

L_E = soil erosion load to the water body (g/yr). L_E is constituent-specific and site-specific.

X_e = unit soil loss (kg/m^2·yr). X_e is site-specific and calculated in Eq. 5-33A in the HHRAP.

A_L	=	total watershed area receiving COPC deposition (m^2). A_L is site-specific. The model uses $A_L = 3.927 \times 10^9$ m^2 (estimated as half of the study area).
A_I	=	impervious watershed area receiving COPC deposition (m^2). A_I is site-specific. The model uses $A_I = 0$ m^2.
SD	=	watershed sediment delivery ratio (unitless). SD is site-specific and is calculated using Eq. 5-34 in the HHRAP.
ER	=	soil enrichment ratio (unitless). ER is site-specific. The following recommended values (Table B-4-11 of the HHRAP) are used: 3 for organic COPCs and 1 for inorganic COPCs and ROPCs.
Cs_2	=	constituent concentration in untilled soil (mg/kg). Cs_2 is constituent-specific, site-specific, and is calculated using Eqs. 5-1C, 5-1D, and 5-1E of the HHRAP.
Kd_s	=	soil-water partition coefficient (L/kg or mL/g). Kd_s is constituent-specific. If no Kd_s value exists for an organic constituent, then Kd_s is estimated using Eq. A-2-10 in the HHRAP and a $f_{oc} = 0.0044$ (fraction of organic carbon in soil, site-specific value from average organic carbon measurements [CCN 150854]), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_s is not available and cannot be estimated, the model uses $Kd_s = 0$ mL/g.
BD	=	soil bulk density (g soil/cm^3 soil). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al. 1998).
θ_{sw}	=	soil volumetric water content (mL water/cm^3 soil). θ_{sw} is site-specific. The EPA-recommended default value of 0.2 mL/cm^3 is used (Eq. 5-33 in the HHRAP).
CF	=	units conversion factor of 1×10^{-3} (g/mg).

Since evapotranspiration exceeds precipitation in the Hanford Site area (there is no water to cause erosion; the water goes back up into the air) there is insufficient water available to cause significant erosion of COPCs and ROPCs, thus erosion is expected to be an insignificant soil loss mechanism and an insignificant surface water loading mechanism (refer to Section 6.3). The model therefore sets L_E equal to zero for all constituents.

A.4.6 Fraction of Total Water Body Concentration in the Water Column (f_{wc})

Equation 5-36A (Table B-4-16) in the HHRAP calculates the fraction of total water body COPC or ROPC concentration occurring in the water column (f_{wc}). f_{wc} is used to estimate four other parameters: the fraction of the total water body concentration in the benthic sediment (Eq. 5-36B of the HHRAP), the overall total water body dissipation rate constant (Eq. 5-38 in the HHRAP), the total water body concentration (Eq. 5-35 in the HHRAP), and the water column concentration (Eq. 5-45 in the HHRAP). The equation to estimate f_{wc} for all constituents is:

$$f_{wc} = \frac{\left(1 + Kd_{sw} \cdot TSS \cdot CF\right) \cdot \dfrac{d_{wc}}{d_z}}{\left(1 + Kd_{sw} \cdot TSS \cdot CF\right) \cdot \dfrac{d_{wc}}{d_z} + \left(\theta_{bs} + Kd_{bs} \cdot C_{BS}\right) \cdot \dfrac{d_{bs}}{d_z}} \qquad \text{(Eq. 5-36A in HHRAP)}$$

where:

f_{wc} = fraction of total water body COPC or ROPC concentration in the water column (unitless). f_{wc} is constituent-specific, site-specific, and ranges from 0 to 1.

Kd_{sw} = suspended sediments/surface water partition coefficient (L/kg). Kd_{sw} is constituent-specific. If no Kd_{sw} value exists for an organic constituent, then Kd_{sw} is estimated using Eq. A-2-11 in the HHRAP and a default $f_{oc,sw} = 0.075$ (fraction of organic carbon in suspended sediments), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_{sw} is not available and cannot be estimated, the model uses $Kd_{sw} = 0$ L/kg.

TSS = total suspended solids concentration (mg/L). TSS is site-specific and ranges from 2 to 300 mg/L. The recommended default value of 10 mg/L is used (see Section 5.7.4.1 and Table B-4-16 of the HHRAP).

CF = units conversion factor of 1×10^{-6} (kg/mg)

d_{wc} = average annual depth of water column (m). d_{wc} is site-specific, and varies dramatically for the Columbia River as a result of dams on either end of the Columbia Reach. The model uses an estimated value of $d_{wc} = 8.65632$ m (Columbia Basin Research 2000).

d_{bs} = depth of upper benthic sediment layer (m). d_{bs} is site-specific. The recommended default value of 0.03 m is used (Section 5.7.4 and Table B-4-16 of the HHRAP).

d_z = total water body depth (m), sum of d_{wc} and d_{bs} (refer to definitions in Table B-4-16 of the HHRAP). d_z is site-specific.

C_{BS} = bed sediment concentration (g/cm^3). C_{BS} is site-specific and ranges from 0.5 to 1.5 g/cm^3. The recommended default value of 1 g/cm^3 is used (Section 5.7.4.1 of the HHRAP).

θ_{bs} = bed sediment porosity ($L_{pore\ water}/L_{sediment}$). θ_{bs} is site-specific and ranges from 0.4 to 0.8 $L_{pore\ water}/L_{sediment}$. The recommended default value of 0.6 $L_{pore\ water}/L_{sediment}$ is used (Section 5.7.4.1 of the HHRAP).

Kd_{bs} = bed sediment/sediment pore water partition coefficient (L/kg). Kd_{bs} is constituent-specific. If no Kd_{bs} value exists for an organic constituent, then Kd_{bs} is estimated using Eq. A-2-12 in the HHRAP and a default $f_{oc,bs} = 0.04$ (fraction of organic carbon in bottom sediments), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If no Kd_{bs} value exists for a constituent, and if Kd_{bs} cannot be estimated, the model uses $Kd_{bs} = 0$ L/kg.

A.4.7 Fraction of Total Water Body Concentration in the Benthic Sediment (f_{bs})

Equation 5-36B (Table B-4-16) in the HHRAP calculates the fraction of total water body COPC or ROPC concentration occurring in the benthic sediment (f_{bs}). f_{bs} is used to estimate three other parameters: the overall total water body dissipation rate constant, k_{wt} (see Table B-4-17 in the HHRAP), the benthic burial rate constant, k_b (Eq. 5-43 in the HHRAP), and the bed sediment concentration, C_{BS} (see Eq. 5-47 in the HHRAP). The equation to estimate f_{bs} for all constituents is:

$$f_{bs} = 1 - f_{wc} \qquad \text{(Eq. 5-36B in HHRAP)}$$

where:

f_{wc} = fraction of total water body COPC or ROPC concentration in the water column (unitless). f_{wc} is constituent-specific, site-specific, and ranges from 0 to 1.

A.4.8 Overall Total Water Body Dissipation Rate Constant in Surface Water (k_{wt})

Equation 5-38 (Table B-4-17) in the HHRAP calculates the overall total water body COPC or ROPC dissipation rate constant in surface water (k_{wt}). k_{wt} is used to estimate the total water body concentration (Eq. 5-35 in the HHRAP). The equation to estimate k_{wt} for all constituents (Eq. 5-38 in the HHRAP) is:

$$k_{wt} = f_{wc} \cdot k_v + f_{bs} \cdot k_b \qquad \text{(Eq. 5-38 in HHRAP)}$$

where:

k_{wt} = overall total water body COPC or ROPC dissipation rate constant (yr^{-1}). k_{wt} is constituent-specific, and site-specific.

f_{wc} = fraction of total water body constituent concentration in the water column (unitless). f_{wc} is COPC- and ROPC-specific, site-specific, ranges from 0 to 1, and is calculated in Eq. 5-36A in the HHRAP.

k_v = water column volatilization rate constant (yr^{-1}). k_v is constituent-specific, site-specific, and calculated in Eq. 5-39 in the HHRAP.

f_{bs} = fraction of total water body constituent concentration in the benthic sediment (unitless). f_{bs} is constituent-specific, site-specific, ranges from 0 to 1, and is calculated in Eq. 5-36B in the HHRAP.

k_b = benthic burial rate constant (yr^{-1}). k_b is site-specific and calculated in Eq. 5-43 in the HHRAP.

A.4.9 Water Column Volatilization Rate Constant (k_v)

Equation 5-39 in the HHRAP calculates the water column volatilization rate constant (k_v). k_v is used to estimate the overall total water body dissipation rate constant, k_{wt} (Eq. 5-38 in the HHRAP), which is used to estimate the total water body concentration, C_{wtot} (Section 6.3 of this RAWP and Eq. 5-35 in the HHRAP). The equation to estimate k_v for all constituents (Eq. 5-39 in the HHRAP) is:

$$k_v = \frac{K_v}{d_z \cdot \left(1 + Kd_{sw} \cdot TSS \cdot CF\right)} \qquad \text{(Eq. 5-39 in HHRAP)}$$

where:

k_v = water column volatilization rate constant (yr^{-1}). k_v is constituent-specific and site-specific.

K_v = overall transfer rate coefficient (m/yr). K_v is constituent-specific, site-specific, and is calculated in Eq. 5-40 in the HHRAP.

d_z = total water body depth (m), sum of d_{wc} and d_{bs} (refer to definitions in Table B-4-16 of the HHRAP). d_z is site-specific.

Kd_{sw} = suspended sediments/surface water partition coefficient (L/kg). Kd_{sw} is constituent-specific. If no Kd_{sw} value exists for an organic constituent, then Kd_{sw} is estimated using Eq. A-2-11 in the HHRAP and a default $f_{oc,sw}$ = 0.075 (fraction of organic carbon in suspended sediments), provided the constituent K_{oc} value (soil organic carbon-water partition coefficient) is known. If Kd_{sw} is not available and cannot be estimated, the model uses Kd_{sw} = 0 L/kg.

TSS = total suspended solids concentration (mg/L). *TSS* is site-specific and ranges from 2 to 300 mg/L. The recommended default value of 10 mg/L is used (see Section 5.7.4.1 of the HHRAP).

CF = units conversion factor of 1×10^{-6} (kg/mg).

A.4.10 Benthic Burial Rate Constant (k_b)

Equation 5-43 (Table B-4-22) in the HHRAP calculates the water column loss constant due to burial in benthic sediment (k_b). k_b is used to estimate the overall total water body dissipation rate constant (see Eq. 5-38 in the HHRAP), which is used to estimate the total water body concentration (Eq. 5-35 in the HHRAP). The equation to estimate k_b for all constituents is:

$$k_b = \left(\frac{X_e \cdot A_L \cdot SD \cdot CF_1 - Vf_x \cdot TSS}{A_w \cdot TSS} \right) \cdot \left(\frac{TSS \cdot CF_2}{C_{BS} \cdot d_{bs}} \right) \qquad \text{(Eq. 5-43 in HHRAP)}$$

where:

k_b = benthic burial rate constant (1/yr). k_b is site-specific.

X_e = unit soil loss (kg/m²·yr). X_e is site-specific and calculated in Eq. 5-33A in the HHRAP.

A_L = total watershed area receiving COPC or ROPC deposition (m²). A_L is site-specific. The model uses $A_L = 3.927 \times 10^9$ m² (estimated as half of the study area).

SD = watershed sediment delivery ratio (unitless). *SD* is site-specific and is calculated in Eq. 5-34 of the HHRAP.

CF_1 = units conversion factor of 1×10^3 (g/kg)

Vf_x = average annual volumetric flow rate through the water body (m³/yr). Vf_x is site-specific. The model uses $Vf_x = 1.06 \times 10^{11}$ m³/yr (PNNL 2002).

TSS = total suspended solids concentration (mg/L). *TSS* is site-specific and ranges from 2 to 300 mg/L. The recommended default value of 10 mg/L is used (see Section 5.7.4.1 of the HHRAP).

A_w = average annual water body surface area (m²). A_w is site-specific, a value of A_w = 3.652E+07 m² is used (PNNL 2005b).

CF_2 = units conversion factor of 1×10^{-6} (kg/mg)

C_{BS} = bed sediment concentration (g/cm³). C_{BS} is site-specific and ranges from 0.5 to 1.5 g/cm³. The recommended default value of 1 g/cm³ is used.

d_{bs} = depth of upper benthic sediment layer (m). d_{bs} is site-specific. The recommended default value of 0.03 m is used.

All default values are from Table B-4-22 in the HHRAP, unless otherwise specified.

A.4.11 Overall Transfer Rate Coefficient (K_v)

Equation 5-40 (Table B-4-19) in the HHRAP calculates the overall transfer rate of contaminants from the liquid and gas-phases in surface water (K_v). K_v is used to estimate the load to the water body due to dry vapor diffusion (Eq. 5-30 in the HHRAP), which is used to estimate the total load to the water body (Eq. 5-28 in the HHRAP). K_v is also used to estimate the water column volatilization rate constant (Eq. 5-39 in the HHRAP). The equation to estimate K_v for all constituents is:

$$K_v = \frac{\theta^{(T_{wk}-293)}}{\dfrac{1}{K_L} + \dfrac{R \cdot T_{wk}}{H \cdot K_G}} \qquad \text{(Eq. 5-40 in HHRAP)}$$

where:

K_v = overall transfer rate coefficient (m/yr). K_v is constituent-specific and site-specific.

θ = temperature correction factor (unitless). θ is site-specific. The recommended default value of 1.026 is used (Section 5.7.4.4 and Table B-4-19 of the HHRAP).

T_{wk} = water body temperature (°K). T_{wk} is site-specific and an average value of 285 °K is used (PNNL 2003. 2004, 2005a, 2006, 2007).

K_L = liquid phase transfer coefficient (m/yr). K_L is constituent-specific, site-specific, and is calculated in Eq. 5-41 of the HHRAP.

R = universal gas constant (atm·m^3/mol·°K). A value of $R = 8.205 \times 10^{-5}$ atm·m^3/mol·°K is used (Section 5.7.4.4 and Table B-4-19 of the HHRAP).

H = Henry's Law Constant (atm·m^3/mol). H is constituent-specific. If no value is available for H, then it is estimated using Eq. A-2-3 in the HHRAP if constituent vapor pressure and water solubility data are available. If no H value exists for a constituent, the model sets the overall transfer rate coefficient (K_v) to 0 m/yr.

K_G = gas-phase transfer coefficient (m/yr). K_G is site-specific and the recommended default value of 36,500 m/yr for a flowing river is used (Eq. 5-42A of the HHRAP).

A.4.12 Equation for Calculating Unit Soil Loss (X_e)

Equation 5-33A (Table B-4-13) in the HHRAP calculates the soil loss rate from the watershed (X_e) by using the universal soil loss equation (USLE). X_e is used to estimate the soil loss due benthic burial rate constant (see Eq. 5-43 in the HHRAP). The benthic burial rate constant is used to estimate loss constants that feed into the overall total water body dissipation rate constant (see Eq. 5-2A in the HHRAP), which is used to estimate the total water body concentration, including the water column and bed sediment (Eqs. 5-35 and 5-47 of the HHRAP). The equation to estimate X_e for all constituents is:

$$X_e = \frac{RF \cdot K \cdot LS \cdot C \cdot PF \cdot CF_1}{CF_2} \qquad \text{(Eq. 5-33A in HHRAP)}$$

where:

X_e = unit soil loss (kg/m^2·yr). X_e is site-specific.

RF	=	USLE rainfall (or erosivity) factor (yr^{-1}). RF is site-specific and ranges from 50 to 300 yr^{-1}. The recommended default value of 50 yr^{-1} from EPA 1998 is used.
K	=	USLE erodibility factor (ton/acre). K is site-specific. The recommended default value of 0.39 ton/acre is used.
LS	=	USLE length-slope factor (unitless). LS is site-specific. The recommended default value of 1.5 is used.
C	=	USLE cover management factor (unitless). C is site-specific. The recommended default value of 0.1 is used.
PF	=	USLE supporting practice factor (unitless). PF is site-specific. The recommended default value of 1.0 is used.
CF_1	=	units conversion factor of 907.18 (kg/ton).
CF_2	=	units conversion factor of 4047 (m^2/acre).

All default values are from Table B-4-13 in the HHRAP.

A.4.13 Sediment Delivery Ratio (*SD*)

Equation 5-34 (Table B-4-14) in the HHRAP calculates the sediment delivery ratio (SD) for the watershed. SD is used to estimate several parameters, including the benthic burial rate constant, k_b (see Eq. 5-43 in the HHRAP). Note that the benthic burial rate constant is used to estimate the overall total water body dissipation rate constant, K_{wt} (see Eq. 5-38 in the HHRAP), which is used to estimate the total water body concentration (5-35 in the HHRAP), including the water column and bed sediment (Eqs. 5-35 and 5-47 of the HHRAP). The equation to estimate SD for all constituents is:

$$SD = a \cdot \left(A_L\right)^{-b} \qquad \text{(Eq. 5-34 in HHRAP)}$$

where:

SD	=	watershed sediment delivery ratio (unitless). SD is site-specific.
a	=	empirical intercept coefficient (unitless). The parameter a is site-specific and is determined by the watershed area as follows (EPA 2005):

Watershed Area ($mile^2$)	a (unitless)
area ≤ 0.1	2.1
$0.1 <$ area ≤ 1	1.9
$1 <$ area ≤ 10	1.4
$10 <$ area ≤ 100	1.2
$100 <$ area	0.6

Since the watershed area is > 100 $mile^2$, a site-specific value of $a = 0.6$ is used.

A_L = total watershed area receiving COPC or ROPC deposition (m^2). A_L is site-specific. An estimated value of 3.927×10^9 m^2 (estimated as half of the study area) is used.

b = empirical slope coefficient (unitless). The recommended default value of 0.125 is used (Table B-4-14 in the HHRAP).

A.4.14 Liquid Phase Transfer Coefficient (K_L)

Equation 5-41 (Table B-4-20) in the HHRAP calculates the rate of contaminant transfer from the liquid phase (K_L). The Columbia River is assumed to be a flowing river (as opposed to a quiescent lake or pond). Therefore, the equation to estimate K_L for flowing streams or rivers is used. K_L is used to estimate the overall transfer rate coefficient (Eq. 5-40 in the HHRAP), which is used to estimate the water column volatilization rate constant (Eq. 5-39 in the HHRAP), as well as the load to the water body due to dry vapor diffusion (Eq. 5-20 in the HHRAP), which is used to estimate the total load to the water body (Eq. 5-28 in the HHRAP). The equation to estimate K_L for flowing streams or rivers for all constituents is:

$$K_L = \sqrt{\frac{CF_1 \cdot D_w \cdot u}{d_z}} \cdot CF_2 \qquad \text{(Eq. 5-41A in HHRAP)}$$

where:

K_L = liquid phase transfer coefficient (m/yr). K_L is constituent-specific and site-specific.

CF_1 = units conversion factor of 1×10^{-4} (m^2/cm^2).

D_w = diffusivity of COPC or ROPC in water (cm^2/s). D_w is constituent-specific. If D_w is not available, it can be estimated using Eq. A-2-5 in the HHRAP. If no value is available for D_w, and if it cannot be estimated, then the model uses $D_w = 0$ cm^2/s.

u = current velocity (m/s). u is site-specific. The model uses a value of $u = 1.37$ m/s, based on modeling data from Columbia Basin Research, 2000 (John Day free flow rate of 4.5 ft/sec).

d_z = total water body depth (m). d_z is site-specific and calculated in Table B-4-16 of the HHRAP.

CF_2 = units conversion factor of 3.1536×10^7 (s/yr).

A.4.15 Gas Phase Transfer Coefficient (K_G)

Equation 5-42A (Table B-4-21) defines the rate of contaminant transfer from the gas phase (K_G) for a flowing system (as opposed to a quiescent system). Since the Columbia River is considered a flowing river as opposed to a quiescent lake or pond, parameter values for flowing streams are used for all constituents to estimate K_G. K_G is used to estimate the overall transfer rate coefficient, K_v (Eq. 5-40 in the HHRAP). Note that the overall transfer rate coefficient is used to estimate the water column volatilization rate constant (Eq. 5-39 in the HHRAP), as well as the load to the water body due to dry vapor diffusion (Eq. 5-20 in the HHRAP), which is used to estimate the total load to the water body (Eq. 5-28 in the HHRAP). The equation for K_G for all constituents is:

$$K_G = 36{,}500 \text{ m/yr} \qquad \text{(Eq. 5-42A in HHRAP)}$$

where:

K_G = gas-phase transfer coefficient (m/yr). K_G is constant for flowing streams. The recommended default value of 36,500 m/yr for a flowing river is used.

A.5 Mass-Limited Uptake

A.5.1 Mass-Limited Uptake Factors for Plants

For both aboveground and belowground plants, the concentrations of contaminants in plants due to root uptake are a function of the soil concentration (*Cs*) and soil-to-plant bioaccumulation uptake factor (*Br*). Uptake factors for organic chemicals are calculated using regression equations and can result in over-estimation of plant uptake, therefore, before computing plant uptake, mass-limited uptake factors will be compared to the uptake factors as calculated per the HHRAP guidance (Sections A2-2.12.2 and A2-2.12.3), and the lesser of the two uptake factors will be used to compute plant uptake when experimental or site-specific uptake factors are not available.

From Section 6.6.3.3, the initial soil-to-plant, mass-limited uptake factor is calculated as follows:

Initial Uptake Factor = Soil Density ÷ Plant Yield

and the reasonable maximum uptake factors can be calculated as follows:

Mass-limited Uptake Factor = Initial Uptake Factor × Modifying Factor

Combining the equations above and substituting variables in the equation yields a mass-limited uptake factor equation as follows:

$$Br_{(\text{mass-limited})} = \frac{BD \cdot Z_s}{Yp} \cdot MF \qquad \text{(Equation A-20)}$$

where:

$Br_{(\text{mass-limited})}$	=	final mass-limited, soil-to-plant uptake factor (kg soil/m^2 per kg DW plant/m^2).
BD	=	soil bulk density (g soil/cm^3 soil). A site-specific value of 1.3 g/cm^3 is used (Halvorson et al. 1998) (see Table 6-3).
Z_s	=	soil mixing zone depth (cm). Two values (depths) are used for Z_s: root-zone soil (15 cm) for wild produce, forage, and wild grain, and tilled soil (20 cm) for domestic produce, silage, and domestic grain (Section 6.2).
Yp	=	yield or standing crop biomass of the edible portion of the plant for aboveground produce (productivity) (kg/m^2). *Yp* is site-specific and plant-type-specific. The recommended default value of 2.24 kg/m^2 (representing a weighted average of fruits and vegetables; HHRAP, Section 5.3.1.4) is used for produce, while a value of 0.15 kg/m^2 for forage (site-specific value, see Wisiol [1984]), and a value of 0.8 kg/m^2 (HHRAP, Section 5.4.1.4) is used for silage. A yield value of 0.25 kg/m^2 was assumed for above ground grains (Baes et al. 1984, Figure 4.14), and 1.17 kg/m^2 for belowground produce[1] (USDA 2009; Baes et. al. 1984).

[1] A yield of 600 cwt (WW)/acre (6.72 kg/m^2) was assumed based on USDA 2009 data for potatoes and onions. A conversion factor of 0.173 kg(DW)/kg(WW) (Baes et. al. 1984, Table 2.3, potato and onion average) is applied resulting a dry weight yield of 1.17 kg/m^2.

MF = adjustments necessary for aboveground versus belowground portions of the plant and for operating duration of the facility that is producing emissions:

- 1/80 for aboveground produce due to root uptake (1/2 × 1/40)
- 1/80 for belowground produce due to root uptake (1/2 × 1/40)
- 1 for forage (no modifying factor applied)
- 1/40 for silage (1/2 modifying factor not applied)
- 1/40 for grain (1/2 modifying factor not applied)

Substituting the appropriate values for each variable and solving for the mass-limited uptake factor yields the following:

For aboveground wild produce:

$$Br_{ag(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 15cm}{2.24\,\frac{kg}{m^2}}\cdot\frac{1}{80} = 1.09$$

For aboveground domestic produce:

$$Br_{ag(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 20cm}{2.24\,\frac{kg}{m^2}}\cdot\frac{1}{80} = 1.45$$

For aboveground forage:

$$Br_{ag(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 15cm}{0.15\,\frac{kg}{m^2}}\cdot 1 = 1300$$

For aboveground silage:

$$Br_{ag(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 20cm}{0.8\,\frac{kg}{m^2}}\cdot\frac{1}{40} = 8.13$$

For aboveground wild grain:

$$Br_{ag(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 15cm}{0.25\,\frac{kg}{m^2}}\cdot\frac{1}{40} = 19.5$$

For aboveground domestic grain:

$$Br_{ag(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 20cm}{0.25\,\frac{kg}{m^2}}\cdot\frac{1}{40} = 26.0$$

For belowground wild produce:

$$Br_{rootveg(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 15cm}{1.17\,\frac{kg}{m^2}}\cdot\frac{1}{80} = 2.08$$

For belowground domestic produce:

$$Br_{rootveg(mass-limited)} = \frac{1.3\,\frac{g}{cm^3}\cdot 20cm}{1.17\,\frac{kg}{m^2}}\cdot\frac{1}{80} = 2.78$$

A.5.2 Mass-Limited Uptake Factors for Livestock and Game

The HHRAP recommended sources for animal uptake factors (*Ba*) for organic chemicals sometimes result in animals predicted to take up more chemical into their tissues than is present in their food, therefore, before computing plant uptake, mass-limited uptake factors will be compared to the uptake factors as calculated per the HHRAP guidance (Sections A2-2.13), and the lesser of the two uptake factors will be used to compute plant uptake when experimental or site-specific uptake factors are not available. This mass-limited uptake factor is not chemical-specific but rather it is a function of exposure duration and body weight. The feed-to-animal tissue mass-limited uptake factor as described in Section 7.1.7.4 (and Section 8.2.5.3) is calculated as follows:

Feed-to-Animal Tissue Uptake Factor = (Exposure Duration) ÷ (Tissue Weight)

Substituting variables in the equation yields a mass-limited uptake factor equation of:

$$Ba_{(mass-limited)} = \frac{ED_{animal}}{FW_{animal}} \quad \text{(Equation A-21)}$$

where:

$Ba_{(mass\text{-}limited)}$	=	mass-limited feed-to-animal tissue uptake factor (days/kg)
ED_{animal}	=	duration to bring animal to market weight (days)
FW_{animal}	=	total mass of animal at market weight (kg)

Substituting values from the table below yields the following:

Animal	Value	Reference/Assumptions
Exposure duration, time to market, ED_{animal} (days)		
Beef	1260	USDA (1996). The approximate maximum age limitation for the Prime, Choice, and Standard grades of steers, heifers, and cows is 42 months.
Pork	180	Oklahoma State University (2007). In outdoor lot systems of swine production, hogs should reach market weight (240 lb.) in 180 days or less.
Poultry	150	9 CFR 381.170(a)(1)(iv). *Roaster or roasting chicken*. A bird of this class is a young chicken (usually 3 to 5 months of age).
Mass of Animal, FW_{animal} (kg)		
Beef	515	USDA (2011), other cattle, live weight of 1137 lbs
Pork	114	USDA (2011), other hogs, live weight of 250 lbs
Poultry	1.50	USDA (2009), pounds sold=1,267,000 lbs, sold for slaughter=384,000 (2008 data)

For beef:

$$Ba_{beef(mass-limited)} = \frac{1260 \text{ days}}{515 \text{ kg FW}} = 2.45 \frac{\text{days}}{\text{kg FW}}$$

For pork:

$$Ba_{pork(mass-limited)} = \frac{180 \text{ days}}{114 \text{ kg FW}} = 2.58 \frac{\text{days}}{\text{kg FW}}$$

For poultry (domestic and wild): $$Ba_{poultry(mass-limited)} = \frac{150 \text{ days}}{1.5 \text{ kg FW}} = 100 \frac{\text{days}}{\text{kg FW}}$$

The equation above is used to estimate mass-limited feed-to-animal tissue uptake factors for beef, pork, and poultry. Estimating a mass-limited feed-to-animal uptake factor for animal products (that is, milk and eggs) is slightly different. The mass limited feed-to-animal product uptake factor is a function of the daily product weight for the animal. The equation for the mass-limited feed-to-animal product uptake factor is:

Feed-to-Animal Product Uptake Factor = 1 ÷ (Daily Product Weight)

Substituting variables in the equation yields a mass-limited uptake factor equation of:

$$Ba_{\text{(mass-limited)}} = \frac{1}{FW_{product}}$$

where:

$Ba_{\text{(mass-limited)}}$	=	mass-limited feed-to-animal product uptake factor (days/kg)
$FW_{product}$	=	total expected weight of animal product each day (kg/day)

Substituting values from the table below yields the following:

Food Product	**Value** (kg FW/day)	**Reference/Assumptions**
Milk	29.0	USDA (2009), annual milk production=23,344 lbs
Eggs	0.0426	USDA (2009), annual eggs produced=1533 million, average layers producing=5,584,000 (2008 data), USDA (2000), egg weight=2.0 oz. (Grade A egg, Table I of §56.218)

For milk: $$Ba_{milk(mass-limited)} = \frac{1}{29.0 \ \frac{\text{kg FW}}{\text{day}}} = 0.0345 \frac{\text{days}}{\text{kg FW}}$$

For eggs (domestic and wild): $$Ba_{eggs(mass-limited)} = \frac{1}{0.0426 \ \frac{\text{kg FW}}{\text{day}}} = 23.5 \frac{\text{days}}{\text{kg FW}}$$

A.6 Derivation of Selected Site-Specific Parameters

Where available, site-specific data is used as input for risk modeling. In some cases, where data for multiple years or conditions is available, arithmetic averages are used. The site-specific inputs for the Columbia River water temperature and flow, Hanford Site annual precipitation, humidity, ambient air temperature, and wind speed fall into this category. These data are available annually as published in the *Hanford Site Environmental Report* (PNNL 2003. 2004, 2005a, 2006, 2007). The *Hanford Site*

Environmental Report is prepared annually and provides an overview of activities at the site, and summarizes environmental data that characterize the Hanford Site. The table below presents the data from reports corresponding to the period for which air modeling was done (2002 - 2006), and provides the average values that are used as site-specific inputs (PNNL 2003. 2004, 2005a, 2006, 2007).

Year	2002	2003	2004	2005	2006	Average Value
River Temperature (deg F)	53.6	55.4	53.6	51.8	51.8	53.2
River Flowrate (m^3/yr) (Priest Rapids)	1.05E+11	9.04E+10	8.92E+10	9.38E+10	1.05E+11	9.68E+10
Precipitation (inches)	5.41	8.14	7.96	6.39	8.46	7.27
Relative Humidity (percent)	53.6	53.7	57.9	55.2	55.3	55.1
Ambient Air Temperature (deg F)	54.4	55.6	54.6	53.5	54.1	54.4
Wind Speed (m/s)	3.5	3.5	3.1	3.2	3.5	3.4

A.7 Derivation of Particulate Emission Factor

The particulate emission factor (*PEF*) represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria. The *PEF* equation is based on the "unlimited reservoir" model developed to estimate particulate emissions due to wind erosion (Cowherd et al. 1985). The *PEF* is computed according to the following equation (EPA 2000):

$$PEF = Q/C \cdot \frac{3600}{0.036 \cdot (1-V) \cdot \left(\frac{u_m}{u_t}\right)^3 \cdot \mathrm{F}(x)} \qquad \text{(Eq. 4 of EPA 2000)}$$

where:

PEF	=	particulate emission factor (m^3/kg)
Q/C	=	inverse of mean concentration at location of exposure ($g/m^2 \cdot s$ per kg/m^3)
V	=	fraction of vegetative cover (unitless)
u_m	=	mean annual windspeed (m/s)
u_t	=	critical wind speed at 7-m height (m/s)
F(*x*)	=	integration function dependent on u_m/u_t derived using Cowherd et al. (1985) (unitless)

define the steps for determining potential respirable particulate emission from wind erosion. The soil particle size distribution, apparent roughness of the site, vegetation cover, presence of a crust on the soil, and presence of non-erodible elements (e.g., large stones) are used to define the potential for suspension.

The potential for wind erosion is quantified in terms of a threshold friction velocity. The greater the value of the threshold friction velocity for a site, the lower the potential for particle suspension. The threshold friction velocity for the contaminated area is determined by knowing the mode of the aggregate particulate size distribution (which is derived from the soil composition) and using a formula derived from the graphical relationship given in equation 5-39 in Streile et al. (1996):

$$u_t^* = \frac{N \cdot e^{(0.412 \cdot \ln(X) + 4.17)}}{100}$$ (Equation 5-39 in Streile et al. [1996])

where:

u^*_t = threshold friction velocity (m/s)
X = aggregate size distribution (mm) = (0.0106) × (Percent Sand) + 0.05
N = nonerodible elements correction factor (dimensionless)

The aggregate size distribution is estimated using X = (0.0106) × (Percent Sand) + 0.05. From the viewpoint of increasing the potential for suspension, this relationship provides relatively realistic estimates for soils with greater than 75 % sand content. For other soils, the relationship provides relatively conservative estimates that are more typical of disturbed soils than undisturbed soils (Streile et al. 1996). The *Hanford Site National Environmental Policy Act (NEPA) Characterization* (Neitzel et al. 2005) describes 15 different surface soil types on the Hanford Site, varying from sand to silty and sandy loam. Burbank loamy sand, which characterizes much of the soil in the region of the Hanford Central plateau where the WTP is located, has a subsoil gravel content of 20 % to 80 %. Assuming the remaining subsoil is sand, a corresponding aggregate distribution (X) of 262 μm to 898 μm is computed. From Figure 3-4 of Cowherd et al. (1985), the corresponding uncorrected threshold friction velocity (u^*_t) ranges from 37.9 to 63.0.

The uncorrected threshold friction velocity (u^*_t) must be adjusted for the effects of any non-erodible elements in the contaminated area. This correction for the fraction of surface coverage is given by Eq. 4-3 in Cowherd et al. (1985). Once the threshold friction velocity has been determined, the critical wind speed at a given height above the surface can be determined using the following equation:

$$u_t = \frac{1}{k} \cdot u_t^* \cdot \ln\left(\frac{z}{z_0}\right)$$ (modified Eq. 4-3 in Cowherd et al. [1985])

where:

u_t = corrected threshold values, or, critical wind speed at 7-m height (m/s)
k = von Karman constant (0.4; dimensionless)
z = reference height above the surface (7 m)
z_0 = surface roughness length (m)

The value of z recommended by Cowherd et al. (1985) is 7 m. The surface roughness length of the site, z_o, is related to the size and spacing of the roughness elements in the area. Figure 2.1 in Cowherd et al. (1985) illustrates z_o for various surfaces. For the land use scenarios of the risk assessment, z_0 will range from 1 (subsistence farming) to 4 (undisturbed grass steppe). Conservatively, a value of z_0 = 1 is used. The corresponding range of critical wind speed at 7 m height is from 6.21 m/s to 10.3 m/s.

The vertical flux of particles smaller than 10 μm in diameter is assumed to be proportional to the cube of the horizontal wind speed (Cowherd et al. 1985). The integration function, F(x), comes from the cubic relationship of the vertical transport of particles and the wind speed. The F(x) function is derived using the following equations from Cowherd et al. (1985):

$$x = \frac{\sqrt{\pi}}{2} \cdot \frac{u_t}{u_m}$$ (Appendix B in Cowherd et al. [1985])

$$\mathrm{F}(x) = 0.18 \cdot \left(8 \cdot x^3 + 12 \cdot x\right) \cdot e^{-x^2}$$ (Appendix B in Cowherd et al. [1985])

where:

- x = ratio of mean annual windspeed and critical wind speed at 7-m height (unitless)
- $\mathrm{F}(x)$ = integration function dependent on u_m/u_t derived using Cowherd et al. (1985) (unitless)
- u_m = mean annual windspeed (m/s)
- u_t = critical wind speed at 7-m height (m/s)

The mean wind speed for the Hanford Site is available in *Hanford Site Environmental Report* (PNNL 2003, 2004, 2005a, 2006, 2007) (see Section A.6). The average windspeed for the period of 2002 through 2006 is 3.4 m/s.

With a critical windspeed in the range of 6.21 m/s to 10.3 m/s, and an average windspeed of 3.4 m/s, the value of x ranges from 1.62 to 2.72, with a corresponding function ($\mathrm{F}(x)$) of to 0.674 to 0.0212.

The EPA default fraction of vegetative cover assumes 50 % vegetative cover and 50 % open soil. The Hanford Site is located in climatic zone 4 (Figure A-1, EPA 2000), so a value of 40.4 is used to describe the inverse mean concentration at center of a 30-acre-square source (average value of cities in climatic zone 4).

Using the parameter values above, the following range of *PEF* values applies to the Hanford Site:

Variable	**Description**	**Value associated with 20 % sand**	**Value associated with 80 % sand**	**Reference**
P_{sand}	percent sand (percent)	20	80	Neitzel et al. (2005). (Section 4.3.3. "Surface Soil" Burbank Loamy Sand)
V	fraction of vegetative cover (unitless)	0.5	0.5	EPA (2000). (Eq. 3 default values)
u_m	mean annual windspeed (m/s)	3.4	3.4	Site-specific (see Section A.6)
Q/C	inverse of mean concentration at location of exposure ($g/m^2 \cdot s$ per kg/m^3)	40.4	40.4	EPA (2000). (Exhibit 10 . Q/C Values by Source Area, City, and Climatic Zone, Seattle, 0.5 acre)
N	nonerodible elements correction factor (unitless)	101.8	101.8	Gillette et al. (1980)
X	aggregate size distribution (mm)	0.262	0.898	Streile et al. (1996)
u^*_t	threshold friction velocity (m/s)	37.9	63.0	

Variable	Description	Value associated with 20 % sand	Value associated with 80 % sand	Reference
r	von Karman constant (unitless)	0.4	0.4	Cowherd et al. (1985). (Figure 3-6 for plowed field, Eq. 4-3)
z	reference height above the surface (m)	7	7	
z_0	surface roughness length (m)	1	1	
u_t	critical wind speed at 7-m height (m/s)	6.21	10.3	
x	ratio of mean annual windspeed and critical wind speed at 7-m height (unitless)	1.62	2.72	Resulting computed values
F(*x*)	integration function (unitless)	0.674	0.0212	
PEF	particulate emission factor (m^3/kg)	7.58×10^7	1.10×10^{10}	

The actual *PEF* for the Hanford Site varies with the location, and most likely falls within the range predicted above (7.58×10^7 m^3/kg to 1.10×10^{10} m^3/kg). To estimate the exposure point concentration of resuspended dust particles, the soil concentration is divided by the *PEF* (refer to modified HHRAP Table C-2-1 and modified Eq. 3 of EPA (2000) as described in Section 7.1.5.2). Therefore, a lower *PEF* will yield a higher (or more conservative) estimate of the exposure point concentration of resuspended dust particles. The *PEF* of 7.58×10^7 m^3/kg will be used in the initial risk assessment for the WTP. If the initial assessment of risks indicates that inhalation of resuspended soil is a critical pathway (i.e., the pathway contributes an unacceptable amount of risk), then additional and more accurate site-specific information will be sought and a more accurate *PEF* will be determined for use in the final risk assessment.

A.8 Derivation of Alternate American Indian Scenario Consumption Rates

A.8.1 Alternate American Indian Scenario #1

The lifestyle and exposure parameters of the first alternate subsistence American Indian resident are primarily based on data from *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (Harris and Harper 2004) and *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments* (Harris 2008). Other parameters were taken from the "A Native American Exposure Scenario" (Harris and Harper 1997) or from EPA's *Exposure Factors Handbook* (EFH, EPA 1997). Children's exposure parameters were developed by proportioning the child caloric intake reported in the *Child-Specific Exposure Factors Handbook* (CSEFH, EPA 2008) according to the various proportions of meat, vegetable, roots, etc. in the diet of the adult American Indian member as reported in the guidance documents provided by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). The derivation of food consumption rates is shown in the following tables. Data from Figure 1 of Harris (2008) was used to derive child consumption rates by applying the adult diet caloric intake (as percent of calories for each food category) to a child caloric consumption rate of 1466 kcal/day. The child caloric consumption rate of 1466 kcal/day is based on the average food-energy intake for children ages 3 to 5 shown in Table 6-35 of the CSEFH. Consumption rates are converted to units appropriate to RAWP equations by dividing the daily intake by the receptor weight[2].

Consumption rates prorated for children

	Data for Adult Consumption (Harris 2008)				Diet prorated for children	
Food Category	**g/day**	**kcal/100g**	**kcal/day**	**Percent of calories**	**g/day**	**kcal/day**
Aboveground Produce						
Berries, Fruits	125	100	125	6 %	88	88
Other vegetation (lichen, pith, cambium)	40	100	40	2 %	29	29
Greens, Tea, Medicines, Spices	133	30	40	2 %	98	29
Honey, Sweeteners	15	275	41	2 %	11	29
Seeds, Nuts, Grain	24	500	120	5 %	15	73
Belowground Produce						
Bulbs (onions, other)	40	30	12	1 %	49	15
Roots, Tubers	400	100	400	18 %	264	264
Meats						
Fish	620	175	1085	49 %	410	718
Game, large & small	125	175	219	10 %	84	147
Fowl & Eggs	62	200	124	6 %	44	88
Totals	1584	1685	2205.9	100 %	1091	1466

See Figure 1 of Harris (2008).

Aboveground produce consumption rates were derived by summing applicable consumption rate data for selected food types as shown below.

Consumption rate for aboveground produce (CR_{ag})

	Adult		Child	
Food Category	**g/day**	**kg/kg·day**	**g/day**	**kg/kg·day**
Berries, Fruits	125	0.0018	88	0.0059
Other vegetation (lichen, pith, cambium)	40	0.00057	29	0.0020
Greens, Tea, Medicines, Spices	133	0.0019	98	0.0065
Honey, Sweeteners	15	0.00021	11	0.00071
Seeds, Nuts, Grain	24	0.00034	15	0.00098
Totals (CR_{ag})	**337**	**0.0048**	**240**	**0.016**

[2] Conversion of g/day to kg/kg·day (divide by receptor body weight and convert g to kg):
Adult: kg/kg·day = (g/day) / 70 kg / (1000 g/kg)
Child: kg/kg·day = (g/day) / 15 kg / (1000 g/kg)

Belowground produce consumption rates were derived by summing applicable consumption rate data for selected food types as shown below.

Consumption rate for belowground produce (CR_{bg})

	Adult		Child	
Food Category	**g/day**	**kg/kg·day**	**g/day**	**kg/kg·day**
Bulbs (onions, other)	40	0.00057	49	0.0033
Roots, Tubers	400	0.0057	264	0.018
Totals (CR_{bg})	**440**	**0.0063**	**313**	**0.021**

Fish, game and fowl consumption rates are summarized below. Per Harris (2008), organ consumption is assumed to account for 10 % of the caloric intake for fish and game.

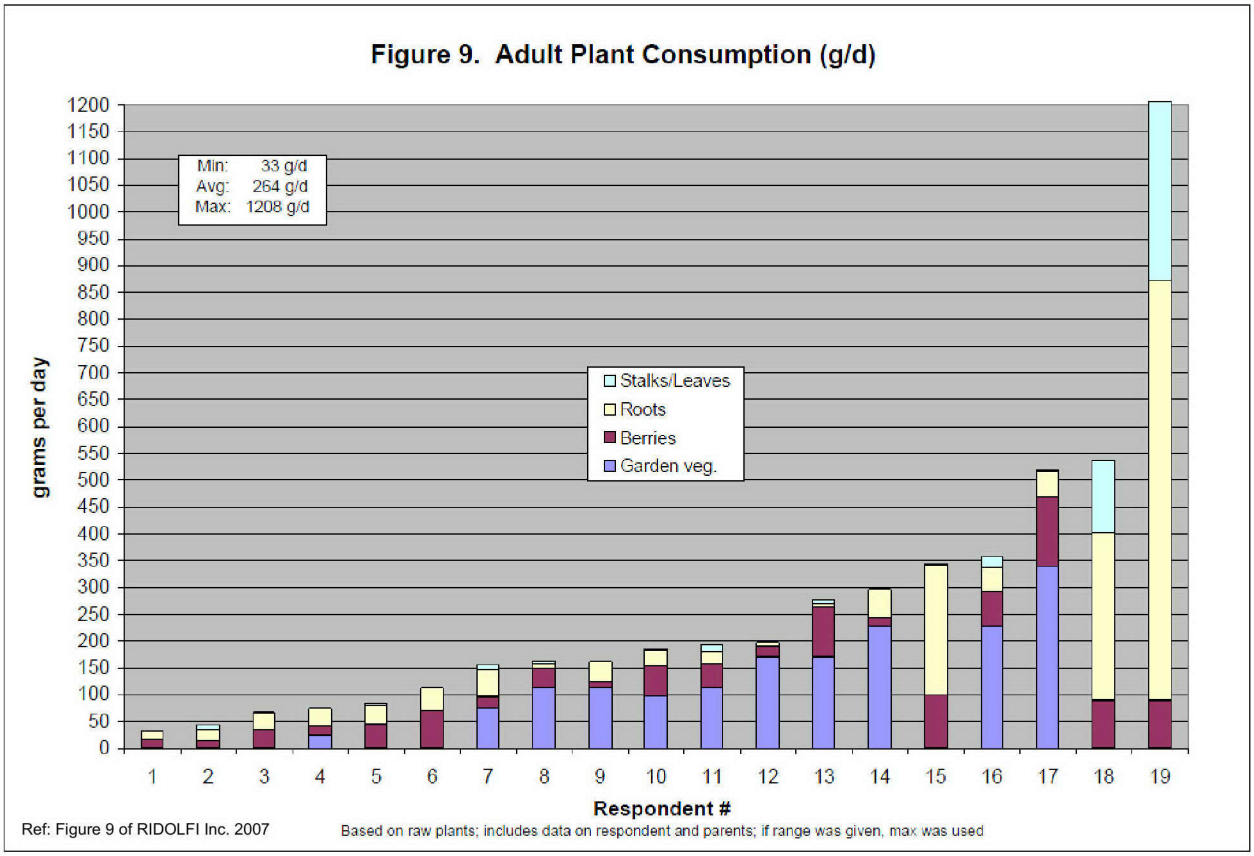
Consumption rates for fish, game and fowl

	Adult		Child	
Food Category	**g/day**	**kg/kg·day**	**g/day**	**kg/kg·day**
Fish (CR_{fish})	558	0.0080	369	0.025
Fish ($CR_{fish\ organs}$)	62	0.00089	41	0.0027
Game, large & small (CR_{game})	112	0.0016	75	0.0050
Game organs ($CR_{game\ organs}$)	13	0.00018	8.4	0.00056
Fowl & Eggs (CR_{fowl})	62	0.00089	44	0.0029

A.8.2 Alternate American Indian Scenario #2

The lifestyle and exposure parameters of the second alternate subsistence American Indian resident are primarily based on data from *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment* (RIDOLFI Inc. 2007). Other parameters were taken from the EFH. Children's exposure parameters were developed by proportioning the child caloric intake reported in the CSEFH according to the various proportions of meat, vegetable, roots, etc. in the diet of the adult American Indian member as reported in the guidance documents provided by the Yakama Nation. The derivation of food consumption rates is shown in the following tables. Data from Figure 9 of RIDOLFI Inc. (2007) was used to derive consumption rates by extracting data in Figure 9 and computing the averages and relative dietary proportions of domestic and wild food stuffs. The bar graphs of Figure 9 were manually inspected and used to determine the grams per day of domestic (garden) and wild (other) produce consumed by survey respondents. These values were then used to compute domestic and wild produce consumption as percent of the respondent's diet. An average dietary distribution of domestic, wild aboveground, and wild belowground produce of 36 %, 34 %, and 31 % (respectively) was then computed. Consumption rates are converted to units appropriate to RAWP equations by dividing the daily intake by the receptor weight[3].

[3] Conversion of g/day to kg/kg·day (divide by receptor body weight and convert g to kg):
Adult: kg/kg·day = (g/day) / 70 kg / (1000 g/kg)
Child: kg/kg·day = (g/day) / 16 kg / (1000 g/kg) (note: per RIDOLFI Inc. 2007, a child weight of 16 kg is assumed)



Assessment (manual tally) of Figure 9 data (RIDOLFI Inc. 2007)

Respondent	Total produce (g/day)	From domestic produce (g/day)	Percent of diet that is domestic produce	From wild aboveground produce (stalks, leaves, berries) (g/day)	Percent of diet that is wild aboveground produce	From wild belowground produce (roots) (g/day)	Percent of diet that is wild belowground produce
1	33	0	0 %	20	61 %	13	39 %
2	45	0	0 %	25	56 %	20	44 %
3	70	0	0 %	40	57 %	30	43 %
4	75	25	33 %	20	27 %	30	40 %
5	110	0	0 %	50	45 %	60	55 %
6	110	0	0 %	65	59 %	45	41 %
7	155	75	48 %	35	23 %	45	29 %
8	160	110	69 %	45	28 %	5	3 %
9	160	110	69 %	15	9 %	35	22 %
10	180	95	53 %	65	36 %	20	11 %
11	190	110	58 %	60	32 %	20	11 %
12	200	165	83 %	25	13 %	10	5 %
13	275	165	60 %	105	38 %	5	2 %
14	300	225	75 %	20	7 %	55	18 %
15	345	0	0 %	100	29 %	245	71 %
16	360	225	63 %	85	24 %	50	14 %

Assessment (manual tally) of Figure 9 data (RIDOLFI Inc. 2007)

Respondent	Total produce (g/day)	From domestic produce (g/day)	Percent of diet that is domestic produce	From wild aboveground produce (stalks, leaves, berries) (g/day)	Percent of diet that is wild aboveground produce	From wild belowground produce (roots) (g/day)	Percent of diet that is wild belowground produce
17	520	340	65 %	125	24 %	55	11 %
18	540	0	0 %	230	43 %	310	57 %
19	1208	0	0 %	428	35 %	780	65 %
Average	**264**	**87**	**36 %**	**82**	**34 %**	**96**	**31 %**

The dietary distribution of domestic, wild aboveground, and wild belowground produce was then applied to the proposed vegetable and fruit consumption rates reported in Table 6 of RIDOLFI Inc. (2007). A diet distribution of 36 % domestic produce, 34 % wild aboveground produce, and 31 % belowground produce was applied to an adult intake of 1417 g/d, and a child intake of 314 g/day.

Consumption rates for produce

	Adult Consumption		Child Consumption	
Food Category	**g/day**	**kg/kg·day**	**g/day**	**kg/kg·day**
Vegetables	1118	0.016	187	0.012
Fruit	299	0.0043	127	0.0079
Total Produce	1417	0.020	314	0.020
Domestic Produce (CR_{ag}) (36 % of diet)	504	0.0072	112	0.0070
Wild Aboveground Produce ($CR_{ag\ wild}$) (34 % of diet)	481	0.0069	106	0.0067
Wild Belowground Produce (CR_{bg}) (31 % of diet)	433	0.0062	96	0.0060

Assumptions regarding the receptor's dietary distribution of domestic livestock and wild game animals was based on a compendium of available sources. RIDOLFI Inc. (2007) states that approximately 60 % of meat consumed is domestic (Section 3.2.2, p. 20). Data from Harris (2008) indicates poultry is 33 % of the game & fowl diet for adults (Figure 1 shows 62 g/day for fowl and eggs, verses 125 g/day for game animals). Thus, for this American Indian scenario, it is assumed that of the meats consumed, 60 % is domestic livestock, and 40 % is game. Furthermore, it is assumed within those categories, approximately 1/3 is poultry and fowl, while the remaining 2/3 is other livestock (beef) and game (deer). From Table 7 or RIDOLFI Inc. (2007), it is assumed that the daily adult consumption of meat products is 704 g/day, and the child's consumption is 212 g/day. This is summarized in the table below.

Consumption rates for meat products

	Adult Consumption		Child Consumption	
Food Category	**g/day**	**kg/kg·day**	**g/day**	**kg/kg·day**
Total meat products	704	0.010	212	0.013
Domestic poultry (60 %×33 %)	139	0.0020	42	0.0026
Domestic livestock (beef) (60 %×67 %)	283	0.0040	85	0.0053
Wild fowl (40 %×33 %)	93	0.0013	28	0.0017
Wild game (deer) (40 %×67 %)	189	0.0027	57	0.0036

Per RIDOLFI Inc. (2007), the adult American Indian receptor consumes 1.2 L/day of milk, and the child consumes 0.5 L/day of milk presumable from local dairy cows. This receptor also consumes 519 g/day and 363 g/day of fish (adult and child consumption, respectively). These consumption rates are summarized below.

Other consumption rates

Food Category	Adult Consumption		Child Consumption	
	L/day or g/day	kg/kg·day	L/day or g/day	kg/kg·day
Milk	1.2	0.017	0.5	0.031
Fish	519	0.0074	363	0.023

No organ consumption is reported in RIDOLFI Inc. (2007) so no organ consumption is assumed for this receptor.

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Table A-1 Soil EPC Equations

Timeframe	**Noncarcinogen** Instantaneous Soil Concentration [a]		**Carcinogen** Average Soil Concentration	
	Without Soil Loss ks = 0	**With Soil Loss** ks > 0	**Without Soil Loss** ks = 0	**With Soil Loss** ks > 0
Current $0 \le T_1 < T_2 \le tD$	$Ds \cdot tD$	Cs_{tD}	$\frac{Ds}{2} \cdot (T_2 + T_1)$	$\frac{Ds}{ks \cdot (T_2 - T_1)} \cdot \left[\left(T_2 + \frac{e^{-ks \cdot T_2}}{ks} \right) - \left(T_1 + \frac{e^{-ks \cdot T_1}}{ks} \right) \right]$
Future $0 < tD \le T_1 < T_2$	$Ds \cdot tD$	Cs_{tD}	$\frac{Ds}{2} \cdot (T_2 + tD)$	$\frac{Cs_{tD}}{ks \cdot (T_2 - T_1)} \cdot \left(e^{-ks \cdot (T_1 - tD)} - e^{-ks \cdot (T_2 - tD)} \right)$
Spanning Current to Future $0 \le T_1 < tD < T_2$	$Ds \cdot tD$	Cs_{tD}	$\frac{Ds}{2 \cdot (T_2 - T_1)} \cdot \left(T_2 \cdot tD - T_1^2 \right)$	$\frac{Ds}{ks \cdot (T_2 - T_1)} \cdot \left[tD - T_1 + \frac{e^{-ks \cdot tD} - e^{-ks \cdot T_1}}{ks} + \frac{Cs_{tD}}{Ds} \cdot \left(1 - e^{-ks \cdot (T_2 - tD)} \right) \right]$

Note: $Cs_{tD} = \frac{Ds \cdot \left(1 - e^{-ks \cdot tD}\right)}{ks}$

Cs_{tD} = instantaneous soil concentration at time *tD* (mg COPC/kg soil).

Ds = deposition term to soil (mg/kg·yr). *Ds* is constituent-specific, site-specific, and depth-specific.

ks = overall soil loss constant due to all processes (yr^{-1}).

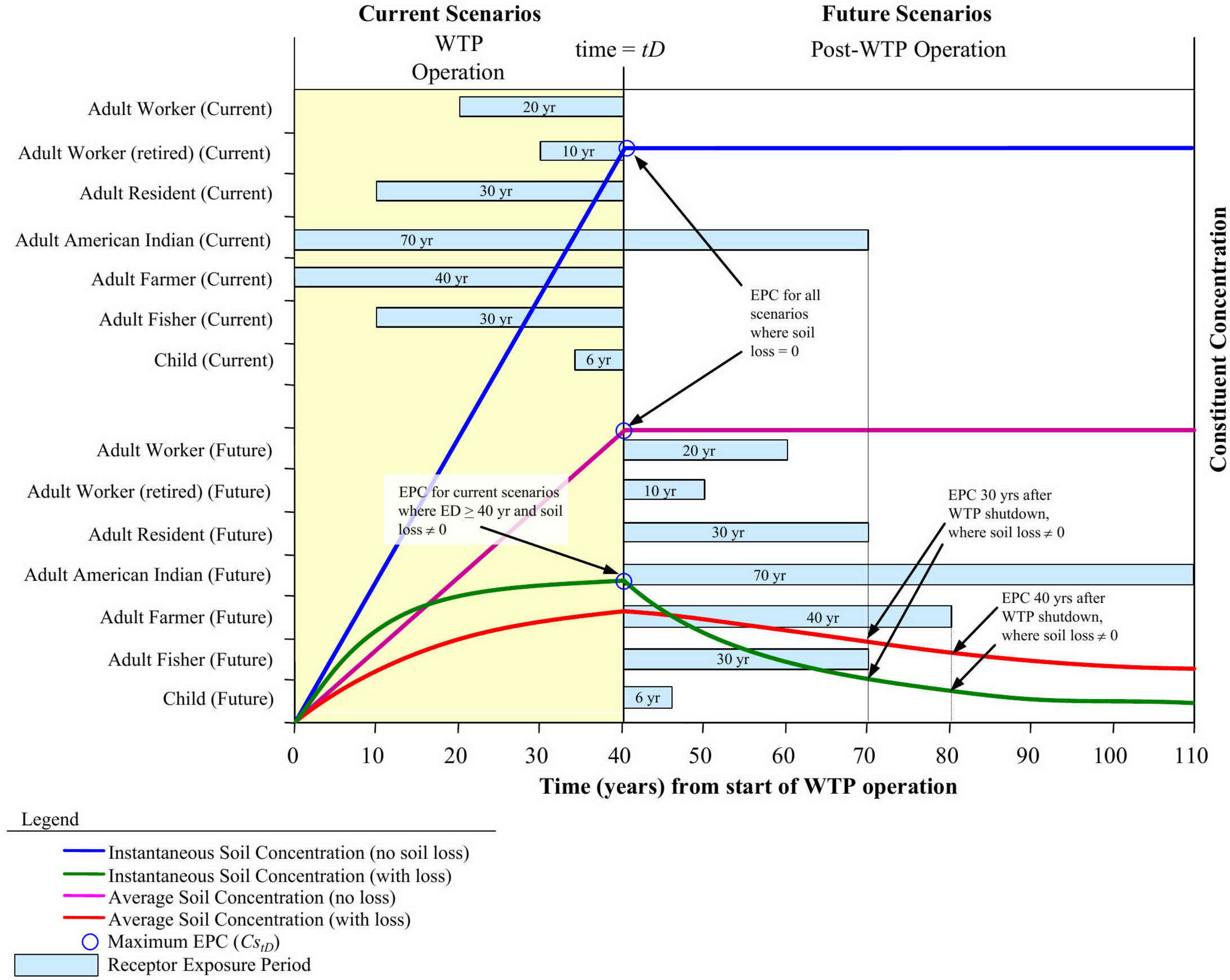
T_1 = the time at the start of exposure (yr).

T_2 = the time at the end of exposure (yr).

tD = the time at the end of emissions/deposition (yr).

a Since noncarcinogenic risk is based on a threshold value (the reference dose), HHRAP (Section 5.2.1) recommends that the maximum instantaneous concentration should be used for risk assessment.

1 **Figure A-1 Receptor Exposure and Instantaneous and Average Soil Concentrations**



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Appendix B

Radiological Risk Assessment Issues

Appendix B
Radiological Risk Assessment Issues

Contents

Tetra Tech EM Inc. Letter extracted from record copy CCN 019247.

Tetra Tech EM Inc. Letter

Tetra Tech EM Inc.

One Dallas Centre ◆ 350 N. St. Paul St. ◆ Dallas, TX 75201 ◆ (214) 754-8765 ◆ FAX (214) 922-9715

March 27, 2001

Mr. Jerry Yokel, Project Officer
Department of Ecology
Nuclear Waste Program
1315 W. 4th Street
Kennewick, Washington 99336-6018

Subject: Contract C0000084
Hanford River Protection Privatization Project
Screening Level Risk Assessment Work Plan
Radiological Risk Assessment Issues

Dear Mr. Yokel:

On November 2, 2000, the Washington State Department of Ecology (Ecology) and the U.S. Department of Energy (DOE) met to discuss the screening level risk assessment work plan for DOE's Hanford River Protection Privatization Project . During this meeting, Ecology asked Tetra Tech EM Inc., to evaluate several outstanding radiological risk assessment issues, as follows:

Issue 1: Prepare a brief report addressing the potential volatility of the radionuclides listed in RAWP-72 with respect to their becoming airborne in a sweat lodge (i.e., water containing these radionuclides splashed onto hot rocks to make steam).

Issue 2: Briefly review the list of 46 radionuclides and identify any other radionuclides, in addition to those listed in RAWP-72, that may become airborne and represent a potential inhalation exposure pathway in a sweat lodge.

Issue 3: Check if the HEAST slope factor for inhalation of tritiated water vapor includes uptake by dermal absorption.

Issue 4: Check to determine if dermal absorption of I-129 can be a significant contributor to risk relative to inhalation.

Issue 5: Check to determine if I-129 can represent an external exposure risk from plume immersion which may be significant relative to the risk it represents by inhalation.

Issue 6: Prepare a brief statement defining the level of exposure that may be considered a LOAEL for radionuclides (e.g., 1 to 5 rem).

Issue 7: Provide a brief report on the concentrations of naturally occurring and ubiquitous manmade radionuclides in mother's breast milk.

Mr. Jerry Yokel
Washington State Department of Ecology
March 27, 2001
Page 2

The Attachment presents responses to each issue. The responses were prepared by Dr. John Mauro of Sandy Cohen & Associates. If you have any questions, please me at (214) 740-2022.

Sincerely,

William P. Desmond, Ph.D.
Senior Environmental Scientist

cc: J. Pankanin, Tetra Tech EM Inc.
J. Mauro, Sandy Cohen & Assoc.
file

Attachment to Tetra Tech EM Inc. Letter

ATTACHMENT

This attachment discusses several issues raised during a meeting on November 2, 2000, between the Washington Department of Ecology and the U.S. Department of Energy (DOE). The purpose of the meeting was to discuss the draft screening level risk assessment work plan for DOE's Hanford River Protection Privatization Project.

Issue 1: Prepare a brief report addressing the potential volatility of the radionuclides listed in RAWP-72 with respect to their becoming airborne in a sweat lodge (i.e., water containing these radionuclides splashed onto hot rocks to make steam).

Issue 2: Briefly review the list of 46 radionuclides and identify any other radionuclides, in addition to those listed in RAWP-72, that may become airborne and represent a potential inhalation exposure pathway in a sweat lodge.

These two issues were formulated into the following question, which the discussion below attempts to answer:

> Assuming that radionuclides contaminate surfaces waters and these surface waters are used by native Americans in sweat lodges, what radioactivity exposure problems might result?

The Sweat Lodge

To prepare for a sweat lodge ceremony, igneous rocks such as lava are heated outside the lodge in a fire pit fueled with wood logs. (Lava tends to hold its heat well.) It takes several hours to heat the rocks, which may be about the size and shape of a man's head, to the required red heat. According to William Grosshandler, Acting Chief, Fire Sciences Division, National Institute for Science and Technology (301- 971-2310), the temperature of the glowing coals in an intense wood fire is about 1700°C, while the flame temperature is about 1200°C. Rocks heated to a dull red heat will have a temperature of about 650°C. The sweat lodge generally consists of a frame of bent willow boughs covered with blankets and tarpaulins. The entrance to the sweat lodge is covered with blankets. A typical sweat lodge might be about 10 feet in diameter and roughly hemispherical in shape. When it is time for the ceremony to begin, a certain number of heated rocks are brought into the lodge one-by-one and placed in a central pit in a ritual manner. Depending on the particular ritual, this might involve twelve rocks. When the heated rocks are in place, the entrance is sealed, water is sprinkled onto the rocks, and prayers and meditation begin. Four such rounds of ritual comprise the ceremony. Each round is about 45 minutes.

Information presented above was obtained at the following Internet sites:

- http://www.ausbcomp.com/redman/sweat_lodge.htm
- http://www.crystalinks.com/sweatlodges.html
- http://www.welcomehome.org/rob/sweat/sweat.html

Aerosols in a Sweat Lodge

Emissions from the vitrification process are expected to be either gaseous species (e.g., CO_2, H_2O, I_2) or solid particulates (e.g., metal oxides and/or silicates).[1] Some fraction of the gaseous species will dissolve in surface waters on contact as H_2O, I^-, or CO_3^{-2}. Some fraction of the solid particulate emissions may also fall onto surface waters. Some of these particulates may settle to the bottom of the body of water, some may dissolve in the water, and some may remain suspended in the water as colloidal particles. Particles which settle out will not contribute to the types of exposures addressed here.

As noted above, water is sprinkled on the heated rocks in the sweat lodge to produce a steam-laden atmosphere. Any tritium, as tritiated water, would be vaporized in the sweat lodge. Similarly, any carbon-14 existing as dissolved carbonic acid would also be vaporized. Other dissolved radioactive species (e.g., metal ions and I-) would most likely remain on the igneous rocks as metal salts which might or might not subsequently evaporate depending on the chemical form of the resulting compounds. The melting and boiling points of some possible compounds are listed in Table 1 (Hdbk 1954).

It can be seen from Table 1 that if antimony chloride or antimony iodide is formed as a result of evaporation, these compounds could volatilize. Selenium, if present as the oxide, could also vaporize under expected sweat lodge conditions.

Ruthenium metal is quite stable and oxides slowly in air at temperatures above 800°C. The metal does not react with air at room temperature. The oxide, RuO_4, is highly volatile with a quoted boiling point of either 40°C or 130°C (**http://www.emsdiasum.com/ems/techdata/57.html).** However, this oxide can not be formed from the elements (http://www.britannica.com/bcom/eb/article/2/0,5716,119792+28+110614,00.html); rather, complex chemical synthesis techniques are required. Consequently, volatilization of ruthenium is not expected to represent a realistic exposure pathway.

Cesium metal boils at about 690°C. As a result, if the element is present in metallic form, perhaps due to decomposition of the oxide, it would not be vaporized in the sweat lodge. If the cesium salts, such as the chloride, iodide, or sulfate, reformed on the heated rocks after the steam had evaporated, none of these compounds would be expected to volatilize.

It is also possible that, instead of remaining as evaporative salts on the heated rocks, some of the dissolved species could be physically airborne as an aerosol mist if the boiling process is sufficiently violent. Whatever mechanism is responsible for the generation of aerosols (vaporization, mechanical entrainment, or volatilization), the quantities of such materials will likely be relatively small since only small quantities of water are used in the ceremonies. For example, consider a sweat lodge in the form of a hemisphere 10 feet in diameter. The lodge will contain about 262 cubic feet of air. Assuming that the lodge contains saturated air at a temperature of 100°F (38°C), then the air will contain 0.043 lb of water vapor per pound of dry air, and the saturated air will have a specific volume of 15.1 cubic feet per pound of dry air (Perry's 1984). Thus, there will be 0.74 lbs of water vapor in the lodge (261 ft^3 x 0.043 lb of H_2O/lb dry x lb dry air/15.1 ft^3). Since a gallon of water weighs 8.3 pounds, the amount of water required to saturate the air in the sweat lodge is about 0.1 gallons. Hence, the total amount of a contaminant airborne in the sweat lodge at any given time would not exceed the amount of the contaminant that is in about 0.1 gallon of water.

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[1] Joule-heated ceramic melters used in the vitrification of HLW operate at about 1100°C in an oxidizing atmosphere. Thus, solid particulates are expected to be oxides or silicates.

TABLE 1
MELTING POINTS AND BOILING POINTS OF SELECTED INORGANIC COMPOUNDS

Compound	Melting Point (°C)	Boiling Point (°C)
$SbCl_3$	74	**234**
SbI_3	167	**401**
Sb_2O_3	656	1550
$BaCl_2$	962	1560
BaI_2	740	NR
BaO	1923	NR
$BaSiO_3$	1604	NR
$BaSO_4$	1580	NR
$CdCl_2 \cdot 2.5H_2O$	568	960
CdI_2	NR	713
CdO	NR	900-1000 (d)
$CdSO_4$	NR	1000
CsCl	646	1290
CsI	621	1280
Cs_2O	360-400 (d)	NR
Cs_2SO_4	1010	NR
CoO	1800 (d)	NR
$CoSO_4$	989	NR
$EuCl_3$	623	NR
NiO	2090	NR
$RaCl_2$	1000	NR
$RuCl_3$	>500 (d)	NR
$SmCl_3$	678	NR
SmI_3	820	NR
SeO_2	NR	**316**
$SrCl_2$	873	NR

Compound	Melting Point (°C)	Boiling Point (°C)
$Sr(OH)_2$	375	NR
SrO	2430	NR
$SrSO_4$	1580 (d)	NR
$SnCl_2$	246	**623**
SnO	700-950 (d)	NR
$ThCl_4$	720-750 (sub)	NR
YCl_3	680	NR

Notes:

Chemicals with boiler point values in **bold** would be expected to volatilize.

d Decomposes
sub Sublimes
NR Not reported

Recommendation:

Clearly, the quantity of radionuclides that may become airborne in this exposure scenario, and the potential significance of this scenario, will depend on many factors related to the chemical form of the radionuclides, the radionuclide concentration in the water, the temperature of the hot rocks, and the amount of water used in the ceremony. Given the many uncertainties, and the potential that aerosols may be generated by mechanical entrainment in addition to volatilization, it is recommended that a two-step process be employed for the assessment of this pathway. The first step would be a screening process, wherein it would be assumed that all of the radionuclides in the water used in the sweat lodge become airborne. If these levels result in potential risks exceeding 1E-6, a more refined analysis could then be initiated for the more limiting radionuclides.

Issue 3: Check if the HEAST slope factor for inhalation of tritiated water vapor includes uptake by dermal absorption.

The inhalation slope factor for tritiated water vapor reported in Table 4 of HEAST is 9.59 E-14 lifetime risk of cancer per pCi inhaled. This value includes both the risk contribution from the internal dose delivered by the tritium that is inhaled plus the tritium that is taken into the body by dermal absorption. This can be demonstrated by the following calculation:

The risk from inhalation of 1 pCi of tritiated water vapor, not including dermal absorption, is derived as follows:

Dose = 1 pCi x .037 dis/sec-pCi x .0057 MeV/dis x 10 d/.693 x 86400 s/d
x 1.6E-06 erg/MeV x .01 rad-g/erg /70,000 g = 6.0E-11 rad/pCi inhaled

Risk = 6.0E-11 rad/pCi x 7.6E-4 risk/rad = 4.56E-14 risk/pCi inhaled

Other than physical constants, the key parameters in this equation are the effective half-life of tritiated water in the body of 10 days, the body weight of reference man of 70 kg, and the risk coefficient for uniform whole body exposure to ionizing radiation of 7.6E-4 lifetime risk per rad uniform whole body exposure.

As may be noted, the result of the above calculation is about one half the slope factor. Since, it is widely acknowledged that the internal dose from immersion in a plume of tritiated water vapor is about 50% from inhalation and 50% from dermal absorption[2], it is clear that the HEAST slope factor includes a factor of two to account for dermal absorption. A telephone conversation with Michael Boyd of the Office of Radiation and Indoor Air (11/3/00) confirmed this understanding.

Issue 4: Check to determine if dermal absorption of I-129 can be a significant contributor to risk relative to inhalation.

Guidance on the possible significance of dermal absorption, relative to inhalation, as a route of exposure to airborne toxicants is provided in "Dermal Exposure Assessment: Principles and Applications," EPA/600/8-91/001B, January 1992. As indicated on page 7-1, as a general rule, "many chemicals due to their low vapor pressure cannot achieve adequate vapor concentrations to pose a dermal hazard" and "for chemicals that can achieve adequate vapor concentrations, it has been assumed that they are primarily absorbed by the respiratory tract." In order to confirm this generalization, it is instructive to evaluate the permeability constant that an I-129 vapor must have in order for it to contribute significantly to uptake relative to inhalation.

Assuming a typical breathing rate of 8,000 m3/yr and an exposed skin surface area of 5,800 cm2[3], the permeability constant (Kp) for a vapor that would correspond to an uptake rate via dermal absorption that is comparable to the uptake by inhalation is derived as follows:

Kp (cm/hr) = (15.2 m3/day x 1E06 cm3/m3)/(5,200 cm2 x 24 hr/day) = 122 cm/hr

Therefore, the permeability constant for I-129 vapor would have to be 122 cm/hr in order for dermal absorption to contribute as much to I-129 uptake as does inhalation. The permeability constants reported in Table 7-1 in the above cited EPA guidance for a broad range of vapor phase organic compounds, which have a high potential for dermal absorption, range from .01 to 14.9 cm/hr. Clearly, dermal absorption of I-129 vapor cannot be a significant contributor to risk relative to inhalation of I-129 vapor.

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[2] See Section 9.3.2 (page 9-4) of "Radiological Assessment - A Textbook on Environmental dose Analysis," Edited by John E. Till and H. Robert Meyer, NUREG/CR-3332, September 1983.

[3] These are the recommended adult long term inhalation value and the upper end exposed skin surface area value on pages 5-24 and 6-5 of "Exposure Factors Handbook," EPA/600/P-95/002Fa, August 1997.

Issue 5: Check to determine if I-129 can represent an external exposure risk from plume immersion which may be significant relative to the risk it represents by inhalation.

I-129 is a pure beta emitter and will, therefore, not deliver a significant external effective whole body dose from plume immersion. As a result, the lifetime risk associated with immersion in an airborne plume of I-129 will essentially be entirely due to the I-129 taken up by inhalation, with a negligible contribution from dermal absorption and external exposure. For example, assuming an airborne plume of 1 pCi/m3 of I-129, and using the HEAST inhalation slope factors, the lifetime risk of cancer due to one year of inhalation exposure to the plume is estimated as follows:

R_{inh} = 1 pCi/m3 x 8000 m3/yr x 1.22E-10 risk per pCi inhaled = 9.76E-07 lifetime cancer risk of cancer from inhalation

Using the external risk conversion factors for I-129 in Federal Guidance Report No. 13, the lifetime risk from the external exposures from one year exposure to a plume containing 1 pCi/m3 of I-131 is estimated as follows:

R_{ext} = 1 pCi/m3 x 1.85E-17 risk per Bq per m3 per sec x 0.037 Bq/pCi x 3.15E7 sec/yr = 2.15E-11 lifetime risk of cancer from external exposure

Hence, the risk from external exposure is over four orders of magnitude smaller than the inhalation risk.

Issue 6: Prepare a brief statement defining the level of exposure that may be considered a LOAEL for radionuclides (e.g., 1 to 5 rem).

The Appendix presents a review of the literature which establishes the bases for defining LOAELs and NOAELs for radionuclides. Though the subject is complex, requiring a number of qualifying statements, in brief, the lowest levels of exposure where clinically significant non-stochastic effects (i.e., the acute effects of radiation) have been observed is about 10 rem. The lowest doses where a statistically significant increase in the incidence of stochastic effects (i.e., cancer) have been observed in an exposed population was about 1 rem uniform whole body exposure delivered over a short period of time to a large population.

Issue 7: Provide a brief report on the concentrations of naturally occurring and ubiquitous manmade radionuclides in mother's breast milk.

Available sources of information were searched, however no data on the natural background and ubiquitous manmade levels of radionuclides in human milk were located. The best evidence found were data on the radionuclide content in cow's milk and produce in the vicinity of Hanford. These data are included in an EXCEL spreadsheet (electronic copy transmitted with this memorandum). These data, which were kindly provided by Bruce Napier of Pacific Northwest National Laboratory, are the results of the 1999 environmental radiological surveillance program (Poston and others 1999). Dr. Napier explained that these annual reports can be obtained at **http://www.hanford.gov/doe/98annualrp/index.html.**

Human milk for women in the vicinity of Hanford would likely contain substantially lower levels of radionuclides than cow's milk since the amount of food and the radionuclide content of the cows' diet is likely to be considerably greater than that of a person. Nevertheless, the data in the spreadsheets represent a baseline that may be useful. In theory, the radionuclide content in human milk in the vicinity of Hanford can be estimated based on human dietary intake, along with the application of biokinetic models on the uptake and retention of radionuclides in human milk.

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Appendix to Tetra Tech EM Inc. Letter

APPENDIX

LOAELs ASSOCIATED WITH RADIATION EXPOSURE

1.0 BACKGROUND INFORMATION

The concept of the "Lowest Observed Adverse Effect Level" (LOAEL) has been employed by public health professionals to assist their efforts to provide policies, guidance, and set regulatory limits in behalf of individuals exposed to radiation and radioactive materials. A LOAEL is the lowest dose in a given study that resulted in an observable harmful health effect. Radiation health effects are generally categorized as either deterministic or stochastic.

1.1 DETERMINISTIC HEALTH EFFECTS

Deterministic effects are those with a threshold dose and where the severity of the health effect(s) is largely defined by the total dose of radiation that is delivered to tissue(s), organ(s), or the whole body of the individual. These health effects are termed "acute radiation health effects" and are generally seen only for relatively large doses above the threshold level that are delivered within a short time period.

Modifying factors that affect the dose-response relationship are numerous and include (1) the rate at which the dose is delivered, (2) the type of radiation (alpha, beta, gamma, or neutron), (3) the exposure pathway (external versus internal exposure from ingestion or inhalation), and (4) age, sex, and health status of the individual.

1.2 STOCHASTIC HEALTH EFFECTS

In contrast to deterministic health effects, the severity of stochastic health effects is not affected by radiation dose. By definition, stochastic radiation effects are "probabilistic" health effects that include (1) cancer induction, (2) genetic effects, and (3) in-utero effects. Thus, the distinguishing feature of the dose-response relationship of a stochastic effect is that the severity is not dose dependent; rather the probability that a stochastic effect may occur is directly proportional to the dose of radiation. A second distinguishing feature of the dose-response relationship of a stochastic effect is that it is assumed to have no threshold. Thus, stochastic health effects associated with chronic low doses or low dose rates of radiation are assumed to represent a linear no-threshold (LNT) dose response. Thus, for even a very small dose of radiation, it is assumed that there is a small but finite risk of cancer, genetic, or in-utero effect.

A familiar example of a stochastic effect is that of smoking and lung cancer. Indisputably, cigarette smoking is a direct cause of human lung cancer, but not all smokers develop lung cancer. Moreover, lung cancer may also be observed in some non-smokers. It is important to note that the "severity" of a lung cancer is independent of whether the individual was a heavy smoker, light smoker, or non-smoker. Thus, the causal relationship of cigarette smoking and lung cancer was established when a higher incidence rate of lung cancer was observed among smokers than among non-smokers. The level of increase was found to be proportional to the amount and duration of cigarette smoking. While large differences in lung cancer rates were readily observable when heavy smokers were compared to non-smokers, these differences diminished to indistinguishable levels for very light smokers or individuals who had smoked only for a very short time.

A similar relationship exists between radiation exposure and several types of stochastic effects. For small doses of radiation, the likelihood that even a single cell will undergo a selective alteration, which leads to a cancer or some other health effect, is extremely low. Furthermore, genetic effects, disturbances in growth and development of an embryo, and cancer can also be caused by chemical, physical, and biological agents, many of which exist naturally in the environment. Thus, even for large doses of radiation, stochastic health effects can be observed only as relatively small increases above the spontaneous incidence that is observable in the normal population.

It must also be acknowledged that the slope of the dose-response relationship for stochastic health effects is also modified by (1) the type of cancer, (2) sex and age at time of exposure, and (3) the type of radiation, pathway of exposure, etc. For example, for a given dose of radiation to the thyroid, the risk of thyroid cancer is highest when radiation is external and the exposed individual is a female child.

A quantitative assessment of the radiation dose-response relationship is further complicated by the fact that cancers (and other stochastic effects) induced by radiation are indistinguishable from those arising spontaneously or caused by other carcinogens. Physicians and pathologists cannot determine, based on tissue type, whether certain lung cancers, for example, are caused by radiation, cigarette smoking, air pollutants, chemicals, or other cancer-causing agents. The ability to detect the common cancers caused by any specific agent is, therefore, limited to statistical analyses. These statistical methods rely on the fact that the incidence of various cancers in a well-defined population can be predicted with reasonable accuracy. For a sufficiently large group of people who have received radiation exposure, an incidence of cancer above the expected level would suggest radiation was a possible cause of the excess number of cancers, but it would not identify radiation as the cause of cancer in any specific individual. Only epidemiologic studies of people exposed to relatively high doses of radiation (greater than 10,000 mrem or 10 rem) have shown such an excess of cancer and have, therefore, demonstrated a causal relationship.

In brief, there exists a voluminous body of data that describes the dose-response relationship and, while there is general consensus at the high end of the dose response, there remains uncertainty and controversy at the low end.

It is the combination of these factors that complicate a quantitative assessment of LOAELs associated with radiation exposure. A detailed and comprehensive discussion is, therefore, beyond the scope of this task. Presented below, however, are select citations of observed radiation health effects and their reported doses that provide useful reference values for LOAELs representing both deterministic and stochastic radiation health effects.

2.0 LOAELs FOR DETERMINISTIC OR ACUTE RADIATION HEALTH EFFECTS

Radiation affects the individual cells that are the building blocks of the tissues and organs of the body. Although all cells can be affected by radiation, some are more sensitive to radiation injury than others. In general, the degree of sensitivity depends on the rate of cell division and the degree of cell differentiation. Thus, the most sensitive cells are undifferentiated rapidly dividing cells that include somatic stem cells and precursor cells to male sperm. The key feature of deterministic effects is that they require a minimum dose that in turn induces cell death in a significant fraction of the exposed cell population that represents a particular tissue/organ.

Human exposure to a single whole-body dose of rapidly delivered radiation of 50 rem or more results in the development of a complex of clinical symptoms, signs, and laboratory findings, which are collectively termed the Acute Radiation Syndrome. In the acute radiation syndrome, the very radiosensitive hemopoietic system is the most prone to manifest evidence of injury. It is only when injury is more severe that gastrointestinal symptoms dominate the picture.

Presented below is a brief discussion of prominent features of the acute radiation syndrome in terms of time of onset and required radiation doses.

2.1 EARLY PRODROMAL SYMPTOMS

The first phase of the acute radiation syndrome is characterized by nausea, vomiting, and diarrhea. The best statistical information on the amount of radiation required to cause various levels of early acute radiation sickness (known clinically as prodromal gastro-intestinal distress) has been derived largely from an analysis of clinical data obtained from the histories of therapeutically and accidentally irradiated persons. The radiation exposures predicted to cause 50% probabilities of loss of appetite, nausea, vomiting, diarrhea and fatigue in such patients are listed in Table A-1.

2.2 HEMOPOIETIC SYNDROME

Clinical changes that develop in the blood following acute exposure often are referred to as the *hemopoietic syndrome*. The earliest change is a fall in the absolute peripheral lymphocyte count. This commences in the first few hours and continues for several days to levels commensurate with the amount of radiation exposure within certain limits. Reduced lymphocyte levels may persist for several weeks. There often is a prompt increase in the leukocyte count during the first few days, then a leveling off for a few more days, following which the granulocyte count will continue to fall with maximum leukopenia developing in two to five weeks. Large doses of radiation may result in severe granulocytopenia within the first seven to ten days, a poor prognostic indicator. Recovery may take several weeks to months. The platelet count usually begins to fall one to two weeks after exposure. Massive radiation exposure doses may cause severe thrombocytopenia to develop much earlier. It may take several months before the platelet counts return to normal. Usually there is a slow decline in the erythrocyte count associated

TABLE A-1
ESTIMATES OF SINGLE RADIATION EXPOSURES THAT WILL CAUSE 50% INCIDENCE OF PRODROMAL RESPONSES (EARLY SYMPTOMS) IN MAN[a]

Level of Radiation Sickness	Single Radiation Exposure (R[b])	95% Confidence Range(R)
Anorexia (loss of appetite for food)	180	150-210
Nausea	260	220-290
Fatigue	280	230-310
Vomiting	320	290-360
Diarrhea	360	310-410

[a] Source: *Radiobiological Factors in Manned Space Flight,* Edited by W. Langham, National Academy of Sciences Publication 1487, National Academy of Sciences, National Research Council, Washington, D.C., 1967.
[b] Measured in air.

with reticulocytopenia, the extent of which depends on the amount of radiation exposure and the severity of the acute radiation syndrome.

One difficulty for defining a LOAEL that involves a deterministic effect is the subjective interpretation for deciding when an "observed effect" is truly "adverse." Acute doses between 300 and 400 rem to hemopoietic tissue are generally regarded as mid-lethal doses, while doses below 100 rem are sub-lethal and result in cell depression that are transient and reversible. Wald and others (1962) provides the following doses-response relationship for each of the major blood-cell components:

> Lymphocyte Count. The absence of any observable decrease has been equated with an exposure dose of less than 25 R; mild decrease and minor lymphopenia with less than a 100 R dose; a fall of greater than 50% and 90% with a dose of greater than 100 R. A pronounced fall has been taken to indicate a dose in the "dangerous range" from 300 to 1,000 rad. A lymphocyte count above 1,500/mm^3 has been considered to mean less than 200 R; less than 1,000/mm^3 to mean 200 to 400 or 500 R; less than 500/mm^3 to mean 400 or 500 to 900 R; and "virtually zero" to mean greater than 900 R.
>
> Neutrophile Count. A depression count in the fourth and fifth week has been equated with a dose of less than 200 R; severe depression in 3 to 5 weeks with a dose of 200 to 400 or 500 R; and severe depression on days 10 to 20 with a dose of 400 or 500 to 900 R.
>
> Platelet Count. A moderate depression of the platelet count during the fourth and fifth week has been associated with less than 200 R; severe depression in 3 to 5 weeks with 200 to 400 or 500 R; and sever depression on days 10 to 20 with 400 or 500 to 900 R.
>
> Reticulocyte Count. An "unequivocal fall" in the reticulocyte count in five days has been equated with a dose or greater than 300 rad.
>
> Mitotic Index. A progressive decrease has been equated with a dose in the 50 to 200 rad range. The absence of mitoses by the fourth day has been equated with a dose of 200 rad or more.

2.3 LOAELs ASSOCIATED WITH HUMAN GAMETES

Fertility. Radiation exposure of an individual's reproductive tissues may affect the production of mature male sperm or female egg cells. Reduced production of these cells may result in the temporary or permanent loss of ability to father or bear children. Sources of information about radiation effects on human fertility are limited to several studies involving medically exposed individuals (Rowley 1974; Upton 1974) and atomic bomb survivors (Blot 1977; Seigel 1966). Additionally, data from animal studies are generally thought to be applicable for estimating these effects on humans. Collectively, human and animal studies indicate that cells responsible for producing sperm in men and ova in women are among the more radiation-sensitive cells of the body. Nevertheless, radiation sensitivity differs between males and females with regard to reproductive fertility. These differences reflect the dynamics of sperm and egg production.

In the females, the ovary contains the complete inventory of about 2 million immature eggs (i.e., oocytes) at the time of birth. Following sexual maturation at puberty, monthly ovulation induces the production of a mature female egg. About 360 to 400 mature female oocytes are produced over her reproductive years. Immature preovulatory egg cells are relatively radioresistant, and following puberty, fertility is impaired only after moderately high doses of 300-400 rad (300,000-400,000 mrad) (NAS 1980). It is not surprising, therefore, that follow-up studies of female Japanese atomic bomb survivors have failed to demonstrate any long-term effects on female (and male) fertility (Blot 1977).

The male testes continuously produce reproductive sperm cells throughout life following sexual maturity. In this steady state of sperm cell renewal, cells are continuously produced to replace functional sperm cells that are expelled or leave the system. The production of mature sperm cells from testicular stem cells involves several cell divisions in which cells undergo dramatic changes. Radiation, which can profoundly impair cell division, is most detrimental in the early stages of sperm cell differentiation. Acute doses of a few rad can temporarily halt cell division at this stage and result in a transient reduction of sperm cell count (ICRP 1984). For increasing doses, the reduction in sperm cell count may lead to temporary or permanent male sterility. Sperm-count studies of males exposed to partial-body irradiation indicate that for gonadal doses of about one hundred to several hundred rad, sterility is temporary, and normal sperm counts resume within one to three years (Upton 1974). Thus, a dose that would permanently sterilize a man is thought to be greater than 500 rad (500,000 mrad) and would exceed the lethal whole body dose for acute radiation exposure (NAS 1980 (BEIR III)).

Among the 38,000 children born to parents irradiated at Hiroshima and Nagasaki with average doses between 31,000 and 39,000 mrem (31 and 39 rem), no statistically significant increase in genetic defects has been seen (Neel 1988; Schull 1981).

3.0 LOAELs ASSOCIATED WITH STOCHASTIC RADIATION HEALTH EFFECTS

Stochastic health effects may not appear for years or even decades after exposure to radiation. Such effects result from specific changes that occur in a few cells or a single cell. Although these selective cellular changes occur rarely, when they do, there is a probability that the altered cell may develop into cancer. If the altered cell is a reproductive cell, there is a possibility of transmitting genetic defects to the progeny of irradiated parents. Also, a developing embryo or fetus could possibly suffer injury if a pregnant woman is exposed to radiation. Thus, radiation-induced stochastic effects may exhibit long latency periods, are probabilistic, and involve biological end-points that occur relatively frequently among unexposed individuals. Because of these constraints, the most informative studies are those that involve (1) a large number of individuals, (2) large radiation doses, and (3) a follow-up period of several decades. These three parameters are frequently used to assess the strength of a study and are quantitatively expressed in person-rem-years.

Summarized in this section are epidemiologic studies grouped by the circumstances in which radiation was received. The categories include:

- Atomic Bomb Survivors
- Medical Exposures
- Fallout from Experimental Weapons Testing
- Occupational Exposures
- Others

3.1 CANCER

This section summarizes information concerning incidences of cancer related to radiation exposures.

3.1.1 Japanese A-Bomb Data

The most intensely studied human populations are the Japanese survivors of the 1945 atomic bombing of Hiroshima and Nagasaki. A-bomb survivors represent the largest group of humans exposed to radiation for whom estimates of individual doses are available. Survivors in the two cities were exposed to the immediate external radiation produced by bomb blasts and to a lesser extent subsequent internal/external exposure from fallout. Of the 75,991 survivors for whom doses were estimated, 34,272 were so far from the hypocenters that their radiation doses were considered negligible (less than 500 mrem or 0.5 rem); thus, they serve as a comparison or "control" group, leaving 41,719 whose doses are estimated at 500 mrem (0.5 rem) or greater. Table A-2 provides the dose distribution for this group of nearly 76,000 individuals.

TABLE A-2
DISTRIBUTION OF EXPOSURE AMONG A-BOMB SURVIVORS

Dose Range (Rad)	Number of Individuals
≈ 0	34,272
1 - 5	19,192
6-9	4,129
10 - 99	15,346
100 - 199	1,946
200 +	1,106

Data on cancer mortality among these 76,000 individuals have been collected and reported over the years. Relative to "controls" and adjusted for age and sex distribution, the number of observed cancer mortalities among the 76,000 A-bomb survivors has been compared to the number of expected mortalities if exposure to radiation had not occurred. The difference between the observed and expected numbers of cancer is assumed to be attributable to radiation exposure. The data in Table A-3 indicate that, of the 5,936 A-bomb survivors who died of cancer, about 340 of these cancers deaths are thought to have been the result of radiation exposure.

The data also define a dose-response in which increasing doses yield an increased percentage of excess cancers, especially for leukemia. However, some numerical estimates embody substantial statistical uncertainties as to the number of cancer deaths induced by radiation. Thus, for doses between 10,000 and 50,000 mrem (10-50 rem), the small number of excess cancers above normal expected levels is difficult to interpret and may reflect random fluctuations that are not linked to radiation exposure. When doses exceed 50,000 mrem (50 rem), the number of excess cancers is sufficient to support a causal link to human cancers.

TABLE A-3
OBSERVED CANCER DEATHS AND NUMBER OF EXPECTED CANCER DEATHS AMONG A-BOMB SURVIVORS

Dose(Rem)	Approx. No. of Survivors	Leukemia				Non-Leukemia			
		Observed	Expected	Excess		Observed	Expected	Excess	
				No.	%			No.	%
0	34,272	58	88	-	0	2443	2593	-	0
1 - 10	23,321	38	61	-	0	1655	1688	-	0
10 - 50	11,500	32	20	12	38	927	866	61	7
50 - 100	3,500	19	6	13	68	329	273	56	17
100 - 200	2,000	23	3	20	87	218	147	71	33
200 +	1,000	30	2	28	93	132	68	64	48
Total	76,000	202	122	80	40	5,734	5,474	260	5

Source: Shimizu 1987.

Hanford Cancer Study. An observable excess cancer rate corresponding to much lower doses of radiation has been reported in studies involving occupationally exposed individuals. Mortality studies of Department of Energy (DOE) site workers were initiated in 1965 by the Atomic Energy Commission, under the direction of Dr. Thomas Mancuso of the University of Pittsburgh. Using mortality data dating to the 1940s, researchers examined the death rates among 44,100 Hanford employees. In 1977, Mancuso and his associates, Alice Stewart and George Kneale, first reported their findings (Mancuso 1977). Their analysis of death certificates for 1,336 "non-exposed" and 2,184 "exposed" male workers who died between 1944 and 1972 found statistically significant associations between cumulative external radiation dose and cancer mortality involving the lung, pancreas, and bone marrow. A subsequent analysis of 4,033 deaths among "radiation monitored" male and female workers also indicated elevated cancer risks among male and female workers for cancer of the pancreas, stomach, lung, and bone marrow (Kneale 1978).

The estimates of cancer risks from these two studies are markedly higher than estimates based on data from the Japanese A-bomb survivors and medically exposed populations. However, many scientists, including those belonging to the National Academy of Sciences, have criticized the studies' methodologies (NAS 1980).

3.1.2 Cancer Induction for Childhood Exposures

Some epidemiologic data suggest that young children may be more sensitive to the carcinogenic effects of radiation. However, these data also have not been without controversy. One such study involved thyroid cancers among individuals exposed during childhood.

Scalp Irradiation for Tinea Capitis in Israel. A total of 10,902 Jewish children immigrating into Israel were studied after having received scalp irradiation for ringworm. All but 60 of the patients were successfully traced and matched against an equal number of nonirradiated controls with tinea capitis and a nonirradiated sibling group of half the size. A sixfold increase in malignant thyroid tumors was found in the irradiated group, compared with the controls. Nine of the 12 thyroid cancers in the irradiated group occurred in females, most of them of the papillary-cell type. Ten of the tumors occurred between 9 and 16 years after therapy. A total of 10 patients who developed cancer had an estimated dose of about 6-9 rads to the thyroid, and the other two received 12 and 18 rads (Modan and others 1974; Modan and others 1977a; Modan and others 1977b).

Scalp Irradiation for Tinea Capitis in New York. Shore, Albert, and Pasternak reported on the second survey of a population of 2,215 irradiated and 1,395 nonirradiated control subjects with tinea capitis (Shore and others 1976). Scalp epilation was accomplished with essentially the same technique as in the Israeli population just discussed; the authors produced almost exactly the dosimetry estimates of 6-10 rads to the thyroid. The average age at irradiation was about 8 years, and the average interval of follow-up was about 20 years after irradiation. No thyroid cancers were observed, although patients with benign ademonas were identified. The variance of this study from that of Modan and others (1977b) may be due to the much smaller size of the population.

3.1.3 Cancer Among Children Exposure in Utero

Earlier epidemiologic studies of in-utero exposure have also yielded inconsistent data regarding the risks of in-utero exposure and subsequent childhood cancers. No significant excess mortalities from juvenile leukemia or other cancers were observed among the 1,630 pregnant Japanese women for embryo/fetus doses of 1,000 to 50,000 mrem (1 to 5 rem) (Jablon 1970). However, a tentative link between in-utero exposure and childhood cancers was reported in a study of pregnant women exposed to diagnostic radiation to the abdomen in doses in the range of 500 to 5,000 mrem (0.5 to 5 rem) (Stewart 1970; Monson 1984).

For years, the surveys involving diagnostic radiation remained controversial. It was suggested that the original surveys were flawed by certain selection criteria of study subjects since many of the radiological procedures were requested by physicians for medical reasons (Oppenheim 1974; Totter 1981). To rule out the possibility that the diagnostic exposure and observed childhood cancers were not causally linked but merely shared a common risk factor, additional studies involving twin pregnancies were undertaken (Harvey 1985). The study focused on twin pregnancies where the diagnostic x-rays were performed solely because the pregnancy involved twins rather than an existing (or suspected) medical problem, as in the previously studied singleton births. When irradiated twin pregnancies were compared to non-irradiated twin pregnancies, a small increase in childhood cancers was observed (Harvey 1985). However, even this improved study design was clouded by the fact that the majority of individual twins affected by childhood cancers were children of mothers with a history of previous pregnancy loss, which may have predisposed these children to cancer. The National Academy of Sciences (NAS 1990) in its reevaluation of all current data nevertheless stated:

> "These complications, notwithstanding the concordance of the studies of twins with the studies of prenatally irradiated singleton births, prompt the tentative conclusion that susceptibility to the carcinogenic effects of irradiation is high during prenatal life."

Based on the limited available human data, the National Academy of Sciences estimated the risk per unit absorbed dose to be between 0.2 and 0.25 excess cancer deaths in the first 10 years of life per 1,000 children each receiving 1,000 mrem (1 rem) of exposure before birth. About 50% of the excess cancers would be expected to be leukemia.

3.2 LOAELS FOR OTHER IN-UTERO DEVELOPMENT EFFECTS

Although animal experiments have shown developmental health effects in the embryo/fetus for radiation doses as low as 5,000 to 10,000 mrem (5 to 10 rem), it can not be demonstrated with certainty that such low doses can induce injury to a human fetus. The evidence is based on the epidemiologic studies of children born to women of Hiroshima and Nagasaki who were exposed to atomic radiation in- utero. The atomic bomb studies were not able to associate doses below 25,000 mrem (25 rem) with developmental abnormalities of the newborn, such as central nervous system defects, skeletal abnormalities, or reduced stature. For doses above 25,000 mrem (25 rem), the most definitive human data concerning the effects of prenatal irradiation are related to brain development (Beebe 1981). In humans, impaired central nervous system development may lead to small-head size and/or severe mental retardation. Severe mental retardation in the fetus is most likely to result from exposure during the 8th to the 15th week of pregnancy, a period when specific cells, including those of the brain, are undergoing crucial development.

Among the approximately 1,600 Japanese subjects studied who had been exposed to radiation in-utero, there were 30 cases of severe mental retardation (Otake 1987). Severe mental retardation was defined as unable to perform simple calculations, to make simple conversation, or to care of himself or herself (i.e., institutionalized). The association between severe mental retardation and small-head size is not clear. Of the 30 cases of severe mental retardation, 18 individuals exhibited small-head size. For the entire study cohort, the number of individuals exhibiting small heads totaled 71 (Wood 1965).

Aside from the classification of severe mental retardation, the study cohort of 1,600 individuals exposed in-utero were also given intelligence tests (i.e., Koga test). Intelligence test (Koga) scores of the exposed individuals revealed that radiation-related effects on intelligence was most pronounced when exposure in-utero occurred 8-15 weeks after conception. The distribution of test scores suggests a progressive reduction in IQ scores with increasing radiation exposure. For fetal exposure in the 8th through 15th week, the reduction in intelligence score under a linear dose-response model was 21-29 points at a dose of 100 rad (100,000 mrad)

(Schull 1988). For a fetal dose of 1 rad (1,000 mrad), the corresponding risk implies a reduction of about one-quarter of one IQ point.

3.3 LOAELs ASSOCIATED WITH GENETIC MUTATIONS

Radiation exposure of reproductive cells have the potential for inducing developmental malformation, still births, neonatal deaths, and ill-health (inclusive of cancer) in the offspring that is the result of a genetic mutation in the exposed gamete. Japanese A-bomb survivors to date have provided important information using biochemical indicators to screen for mutations. In a total of 289,868 locus tests, involving measurements of 28 different protein phenotypes using one-dimensional electrophoresis to detect protein variants, Neel et al. (1980), have found one probable mutation in the offspring of proximally exposed parents, who received an estimated average gonadal exposure of 31-39 rem in the atomic bombings of Hiroshima and Nagasaki. There were no mutations in 208,196 locus tests involving children of distally exposed parents, who received essentially no radiation exposure. These findings correspond to mutation rates of 0.34×10^{-5} per locus per generations in the proximally exposed parents and zero in the distally exposed parents.

However, the significance of this observed gene mutation remains uncertain. Among the 38,000 children born to parents irradiated at Hiroshima and Nagasaki with average doses between 31,000 and 39,000 mrem (31 and 39 rem), no statistically significant increase in genetic defects has been seen (Neel 1988; Schull 1981).

It is also recognized that certain types of cancers have a heritable component. To test the hypothesis that a parent's job exposure to ionizing radiation affects his or her child's risk of cancer, investigators compared this occupational exposure the year before the child's birth for parents of children with and without cancer (Hicks 1984). The parents of 283 children diagnosed with cancer and the parents of controls were identified and classified by profession (i.e., dentists, radiologists, x-ray technicians, etc.) and industry (i.e., nuclear industry, veterinary medicine, industrial radiography, etc.) in which the potential for occupational exposure was high, moderate, or none. The researchers found no evidence of increased cancer risks among children whose parent(s) worked in occupations classified as having high potential exposures. Another study, however, found that leukemia incidence was higher than normal among children fathered by men who had previously received comparatively high exposures (Gardner 1990). However, this observation by no means proves a causal connection between occupational irradiation of a parent and leukemia in the offspring. In fact, any assumed causal relationship is inconsistent with what is known about radiation genetics, mechanisms of leukemogenesis, and the results of other independent epidemiologic studies.

4.0 CONCLUSION

LOAELs between 10 rem (10,000 mrem) and several 10's of rem have been cited in the literature in behalf of deterministic radiation health effects. These effects principally reflect fractional cell death and reduced division of hemopoietic and male reproductive stem cells. However, these low-level effects are transient and reversible and, therefore, require a subjective interpretation of the definition of an “adverse” health effect. Moreover, for deterministic effects, the radiation dose must be delivered over a very short time and would reflect “accidental” conditions of exposure.

LOAELs of less than 10 rem (10,000 mrem) for stochastic radiation health effects are primarily linked to childhood cancer induction (i.e., cancers that result from radiation exposure received during childhood/in-utero, or by genetic mutation of male sperm), and other in-utero effects. However, some of these data remain controversial.

These values must be viewed in context with regulatory exposure limits for members of the public. For all anthropogenic sources of radiation, the regulatory limit for public exposure is 0.1 rem per year (or 100 mrem per year). For a discrete source of radiation exposure, the most common limit for public exposure is 0.025 rem per year (or 25 mrem per year).

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Appendix C

Lists of Common Vascular Plants, Mammals, Common Birds, Amphibians and Reptiles, Plant Species of Concern, and Wildlife Species of Concern

Appendix C
Lists of Common Vascular Plants, Mammals, Common Birds, Amphibians and Reptiles, Plant Species of Concern, and Wildlife Species of Concern

Contents

Tables

References for Appendix C

Project Documents

None

Codes and Standards

None

Other Documents

Neitzel DA, ed., Bunn AL, Cannon SD, Duncan JP, Fowler RA, and others. 2005. *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev 17, Pacific Northwest National Laboratory, Richland, Washington.

Table C-1 Common Vascular Plants Found on the Hanford Site

Scientific Name	Common Name
Shrub-Steppe Species	
Shrub	
Artemisia tridentata	big sagebrush
Artemisia tripartita	threetip sagebrush
Chrysothamnus viscidiflorus	green rabbitbrush
Ericameria nauseousa	gray rabbitbrush
Eriogonum niveum	snow buckwheat
Grayia (Atriplex) spinosa	spiny hopsage
Purshia tridentata	bitterbrush
Perennial Grasses	
Achnatherum hymenoides	Indian ricegrass
Agropyron desertorum (cristatum)[(a)]	crested wheatgrass
Elymus elymoides	bottlebrush squirreltail
Elymus macrourus	thickspike wheatgrass
Koeleria cristata	prairie junegrass
Poa sandbergii (secunda)	Sandberg's bluegrass
Pseudoroegnaria spicata	bluebunch wheatgrass
Sporobolus cryptandrus	sand dropseed
Stipa comata	needle-and-thread grass
Biennial/Perennial Forbs	
Achillea millefolium	yarrow
Arenaria franklinii	Franklin's sandwort
Astragalus caricinus	buckwheat milkvetch
Astragalus sclerocarpus	stalked-pod milkvetch
Balsamorhiza careyana	carey's balsamroot
Brodiaea douglasii	Douglas' clusterlily
Chaenactis douglasii	hoary falseyarrow
Comandra umbellata	bastard toad flax
Crepis atrabarba	slender hawksbeard
Cymopteris terebinthinus	turpentine spring parsley
Erigeron filifolius	threadleaf fleabane
Erysimum asperum	rough wallflower
Fritillaria pudica	yellow bell
Helianthus cusickii	Cusick's sunflower
Lomatium grayi	Gray's desertparsley
Machaeranthera canescens	hoary aster

Table C-1 Common Vascular Plants Found on the Hanford Site

Scientific Name	Common Name
Oenothera pallida	pale eveningprimrose
Penstemon acuminatus	sand beardtongue
Phlox longifolia	longleaf phlox
Psoralea lanceolata	dune scurfpea
Rumex venosus	winged dock
Sphaeralcea munroana	Munro's globemallow
Thelypodium laciniatum	cutleaf ladysfoot mustard
Tragopogon dubius[a]	yellow salsify
Annual Forbs	
Ambrosia acanthicarpa	bur ragweed
Amsinckia lycopsoides	tarweed fiddleneck
Chorispora tenella[a]	blue mustard
Cryptantha circumscissa	matted cryptantha
Cryptantha pterocarya	winged cryptantha
Descurainia pinnata	western tansymustard
Draba verna[a]	spring whitlowgrass
Epilobium paniculatum	tall willowherb
Erodium cicutarium[a]	storksbill
Holosteum umbellatum[a]	jagged chickweed
Lactuca serriola[a]	prickly lettuce
Lepidium perfoliatum	clasping pepperweed
Mentzelia albicaulis	whitestem stickleaf
Microsteris gracilis	pink microsteris
Phacelia linearis	threadleaf scorpion weed
Plantago patagonica	Indian wheat
Plectritis macrocera	white cupseed
Polemonium micranthum	annual Jacob's ladder
Salsola kali[a]	Russian thistle (tumbleweed)
Sisymbrium altissimum[a]	Jim Hill's tumblemustard
Annual Grasses	
Bromus tectorum[a]	cheatgrass
Festuca microstachys	small sixweeks
Festuca octoflora	slender sixweeks
Riparian Species	
Trees and Shrubs	
Morus alba[a]	white mulberry

Table C-1 Common Vascular Plants Found on the Hanford Site

Scientific Name	Common Name
Populus trichocarpa	black cottonwood
Prunus spp.	peach, apricot, cherry
Robinia pseudo-acacia	black locust
Salix amygdaloides[a]	peachleaf willow
Salix exigua	coyote willow
Salix spp.	willow
Perennial Grasses and Forbs	
Agrostis spp. [b]	bentgrass
Alopecurus aequalis [b]	meadow foxtail
Apocynum cannabinum	dogbane
Artemisia campestris	Pacific sage
Artemisia ludoviciana	prairie sagebrush
Carex spp.[b]	sedge
Centaurea repens[a]	Russian knapweed
Coreopsis atkinsoniana	horseweed tickseed
Equisetum spp.	horsetails
Eragrostis spp. [b]	lovegrass
Gaillardia aristata	blanket flower
Grindelia columbiana	Columbia River gumweed
Heterotheca villosa	hairy golden aster
Juncus spp.	rushes
Lupinus spp.	lupine
Phalaris arundinacea(a,b)	reed canary grass
Polygonum persicaria	heartweed
Scirpus spp.[b]	bulrushes
Solidago occidentalis	western goldenrod
Typha latifolia[b]	cattail
Veronica anagallis-aquatica	water speedwell
Aquatic Vascular Species	
Elodea canadensis	Canadian waterweed
Lemna minor	duckweed
Myriophyllum spicatum	spiked water milfoil
Potamogeton spp.	pondweed
Rorippa nasturtium-aquaticum	watercress

Table C-1 Common Vascular Plants Found on the Hanford Site

Scientific Name	Common Name

Source: Neitzel DA, ed., Bunn AL, Cannon SD, Duncan JP, Fowler RA, and others. 2005. *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev 17, Pacific Northwest National Laboratory, Richland, Washington.

[a] Introduced
[b] Perennial grasses and graminoids.

Table C-2 List of Mammals Occurring on the Hanford Site

Scientific Name	Common Name
Shrews (family Soricidae)	
Sorex merriami	Merriam's shrew
Sorex vagrans	vagrant shrew
Evening bats (family Vespertilionidae)	
Antrozous pallidus	pallid bat
Eptesicus fuscus	big brown bat
Lasionycteris noctivagans	silver-haired bat
Lasiurus cinereus	hoary bat
Myotis californicus	California myotis
Myotis leibii	small-footed myotis
Myotis lucifugus	little brown myotis
Myotis volans	long-legged myotis
Myotis yumanensis	Yuma myotis
Pipistrellus hesperus	western pipistrelle
Hares, rabbits (family Leporidae)	
Lepus californicus	black-tailed jackrabbit
Lepus townsendii	white-tailed jackrabbit
Sylvilagus nuttallii	Nuttall's (or mountain) cottontail
Chipmunks, marmots, Squirrels (family Sciuridae)	
Marmota flaviventris	yellow-bellied marmot
Spermophilus townsendii	Townsend's ground squirrel
Spermophilus washingtoni	Washington ground squirrel
Tamias minimus	least chipmunk
Pocket gophers (family Geomyidae)	
Thomomys talpoides	northern pocket gopher
Heteromyid rodents, pocket mice (family Heteromyidae)	
Perognathus parvus	Great Basin pocket mouse
Beavers (family Castoridae)	
Castor canadensis	beaver
Campagnols, mice, rats, souris, voles (family Muridae)	
Lemmiscus curtatus	sagebrush vole
Microtus montanus	montane vole
Mus musculus	house mouse
Neotoma cinerea	bushy-tailed woodrat
Ondatra zibethicus	muskrat
Onychomys leucogaster	northern grasshopper mouse
Peromyscus maniculatus	deer mouse

Table C-2 List of Mammals Occurring on the Hanford Site

Scientific Name	Common Name
Rattus norvegicus	Norway rat
Reithrodontomys megalotis	western harvest mouse
New World porcupines (family Erethizontidae)	
Erethizon dorsatum	porcupine
Coyotes, dogs, foxes, jackals, wolves (family Canidae)	
Canis latrans	coyote
Raccoons (family Procyonidae)	
Procyon lotor	raccoon
Martins, weasels, wolverines, otters, badgers (family Mustelidae)	
Lontra canadensis	river otter
Mustela erminea	short-tail weasel
Mustela frenata	long-tailed weasel
Mustela vison	mink
Taxidea taxus	badger
Skunks (family Mephitidae)	
Mephitis mephitis	striped skunk
Cats (family Felidae)	
Lynx rufus	bobcat
Puma concolor concolor	mountain lion
Caribou, cervids, deer, moose, Wapiti (family Cervidae)	
Cervus elaphus	Rocky Mountain elk
Odocoileus hemionus	mule deer
Odocoileus virginianus	white-tailed deer

Source: Neitzel DA, ed., Bunn AL, Cannon SD, Duncan JP, Fowler RA, and others. 2005. *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev 17, Pacific Northwest National Laboratory, Richland, Washington.

Table C-3 Common Birds Occurring on the Hanford Site

Scientific Name	Common Name
Gaviiformes - Loons or divers	
Gavia immer	common loon
Podicipediformes - Grebes	
Aechmophorus occidentalis	western grebe
Podiceps auritus	horned grebe
Podiceps nigricollis	eared grebe
Podilymbus podiceps	pied-billed grebe
Pelecaniformes - Pelicans and allies	
Pelecanus erythrorhynchos	American white pelican
Phalacrocorax auritus	double-crested cormorant
Anseriformes - Waterfowl	
Anas acuta	northern pintail
Anas americana	American wigeon
Anas clypeata	northern shoveler
Anas crecca	American green-winged teal
Anas cyanoptera	cinnamon teal
Anas discors	blue-winged teal
Anas platyrhynchos	mallard
Anas strepera	gadwall
Aythya americana	redhead
Branta canadensis	Canada goose
Bucephala albeola	bufflehead
Bucephala clangula	common goldeneye
Bucephala islandica	Barrow's goldeneye
Lophodytes cucullatus	hooded merganser
Mergus merganser	common merganser
Oxyura jamaicensis	ruddy duck
Gruiformes - Cranes, rails, and allies	
Fulica americana	American coot
Porzana carolina	sora
Rallus limicola	Virginia rail
Charadriiformes - Shorebirds and allies	
Ardea herodias	great blue heron
Calidris alpinis	dunlin
Gallinago gallinago	common snipe
Larus argentatus	herring gull
Larus glaucescens	red-necked phalarope

Table C-3 Common Birds Occurring on the Hanford Site

Scientific Name	Common Name
Limnodromus scolopaceus	long-billed dowitcher
Nycticorax nycticorax	black-crowned night-heron
Tringa flavipes	lesser yellowlegs
Tringa melanoleuca	greater yellowlegs
Tringa solitaria	solitary sandpiper
Actitis macularia	spotted sandpiper
Calidris mauri	western sandpiper
Casmerodius albus	great egret
Charadrius vociferus	killdeer
Grus canadensis	sandhill crane
Larus californicus	California gull
Larus delawarensis	ring-billed gull
Leucosticte tephrocotis	glaucous-winged gull
Numenius americanus	long-billed curlew
Recurvirostra americana	American avocet
Sterna caspia	Caspian tern
Sterna forsteri	Forster's tern
Galliformes - Chicken-like birds	
Callipepla californica	California quail
Alectoris chukar	chukar
Perdix perdix	grey partridge
Phasianus colchicus	ring-necked pheasant
Falconiformes - Diurnal birds of prey	
Accipiter cooperii	Cooper's hawk
Accipiter striatus	sharp-shinned hawk
Buteo jamaicensis	red-tailed hawk
Buteo regalis	ferruginous hawk
Buteo swainsoni	Swainson's hawk
Circus cyaneus	northern harrier
Falco columbarius	merlin
Pandion haliaetus	osprey
Aquila chrysaetos	golden eagle
Buteo lagopus	northern rough-legged hawk
Falco mexicanus	prairie falcon
Falco sparverius	American kestrel
Haliaeetus leucocephalus	bald eagle

Table C-3 Common Birds Occurring on the Hanford Site

Scientific Name	Common Name
Strigiformes - Owls	
Asio flammeus	short-eared owl
Asio otus	long-eared owl
Athene cunicularia	burrowing owl
Bubo virginianus	great horned owl
Tyto alba	common barn-owl
Coraciiformes - Rollers and allies	
Ceryle alcyon	belted kingfisher
Columbiformes - Pigeons	
Columba livia	rock dove
Zenaida macroura	mourning dove
Caprimulgiformes - Nightjars and allies	
Chordeiles minor	common nighthawk
Phalaenoptilus nuttallii	common poorwill
Apodiformes - Hummingbirds, swifts	
Selasphorus rufus	rufous hummingbird
Piciformes - Woodpeckers and allies	
Colaptes auratus	Northern flicker
Passeriformes - Perching birds	
Agelaius phoeniceus	red-winged blackbird
Ammodramus savannarum	grasshopper sparrow
Amphispiza belli	sage sparrow
Bombycilla cedrorum	cedar waxwing
Carduelis tristis	American goldfinch
Carpodacus mexicanus	house finch
Catherpes mexicanus	canyon wren
Chondestes grammacus	lark sparrow
Cistothorus palustris	marsh wren
Contopus sordidulus	western wood-pewee
Corvus brachyrhynchos	American crow
Corvus corax	common raven
Dendroica coronata	yellow-rumped warbler
Dendroica petechia	yellow warbler
Dendroica townsendi	Townsend's warbler
Empidonax difficilis	Pacific-slope flycatcher
Empidonax hammondii	Hammond's flycatcher
Eremophila alpestris	horned lark

Table C-3 Common Birds Occurring on the Hanford Site

Scientific Name	Common Name
Euphagus cyanocephalus	Brewer's blackbird
Hirundo pyrrhonota	cliff swallow
Hirundo rustica	barn swallow
Icteria virens	yellow-breasted chat
Icterus galbula	Bullock's oriole
Ixoreus naevius	varied thrush
Junco hyemalis	dark-eyed junco
Lanius ludovicianus	loggerhead shrike
Melospiza lincolnii	Lincoln's sparrow
Melospiza melodia	song sparrow
Molothrus ater	brown-headed cowbird
Myadestes townsendi	Townsend's solitaire
Oporornis tolmiei	MacGillivray's warbler
Oreoscoptes montanus	sage thrasher
Passer domesticus	house sparrow
Passerculus sandwichensis	savannah sparrow
Passerina amoena	lazuli bunting
Phalaropus lobatus	gray-crowned rosy finch
Pheucticus melanocephalus	black-headed grosbeak
Pica pica	black-billed magpie
Pipilo erythrophthalmus	rufous-sided towhee
Piranga ludoviciana	western tanager
Pooecetes gramineus	vesper sparrow
Regulus calendula	ruby-crowned kinglet
Regulus satrapa	golden-crowned kinglet
Riparia riparia	bank swallow
Salpinctes obsoletus	rock wren
Sayornis saya	Say's phoebe
Sitta canadensis	red-breasted nuthatch
Spizella breweri	Brewer's sparrow
Spizella passerina	chipping sparrow
Stelgidopteryx serripennis	northern rough-winged swallow
Sturnella neglecta	western meadowlark
Sturnus vulgaris	European starling
Tachycineta bicolor	tree swallow
Tachycineta thalassina	violet-green swallow

Table C-3 Common Birds Occurring on the Hanford Site

Scientific Name	Common Name
Thryomanes bewickii	Bewick's wren
Troglodytes aedon	house wren
Troglodytes troglodytes	winter wren
Turdus migratorius	American robin
Tyrannus tyrannus	eastern kingbird
Tyrannus verticalis	western kingbird
Vermivora celata	orange-crowned warbler
Vermivora ruficapilla	Nashville warbler
Vireo gilvus	warbling vireo
Vireo solitarius	Blue-headed vireo
Wilsonia pusilla	Wilson's warbler
Xanthocephalus xanthocephalus	yellow-headed blackbird
Zonotrichia atricapilla	golden-crowned sparrow
Zonotrichia leucophrys	white-crowned sparrow

Source: Neitzel DA, ed., Bunn AL, Cannon SD, Duncan JP, Fowler RA, and others. 2005. *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev 17, Pacific Northwest National Laboratory, Richland, Washington.

Table C-4 Amphibians and Reptiles Occurring on the Hanford Site

Scientific Name	Common Name
Amphibians	
Ambystoma tigrinum	tiger Salamander
Bufo boreas	western toad
Bufo woodhousii	Woodhouse's toad
Hila regilla	Pacific tree frog
Rana catesbeiana	bullfrog
Scaphiopus intermontanus	Great Basin spadefoot
Reptiles	
Chrysemys picta	painted turtle
Coluber constrictor	western yellow-bellied racer
Crotalus viridis	western rattlesnake
Hypsiglena torquata	night snake
Masticophis taeniatus	striped whipsnake
Phrynosoma douglassii	short-horned lizard
Pituiphis melanoleucus	Great Basin gopher snake
Scleroporus graciosus	northern sagebrush lizard
Thamnophis sirtalis	common garter snake
Uta stansburiana	side-blotched lizard

Source: Neitzel DA, ed., Bunn AL, Cannon SD, Duncan JP, Fowler RA, and others. 2005. *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev 17, Pacific Northwest National Laboratory, Richland, Washington.

Table C-5 Fish Species Occurring in the Hanford Reach

Scientific Name	Common Name
Paddlefishes, spoonfishes, sturgeons (family Acipenseridae)	
Acipenser transmontanus	white sturgeon
Anchovies, herrings (family Clupeidae)	
Alosa sapidissima	American shad
Cyprins, minnows, suckers (family Catostomidae)	
Acrocheilus alutaceus	chiselmouth
Catostomus columbianus	bridgelip sucker
Catostomus macrocheilus	largescale sucker
Catostomus platyrhynchus	mountain sucker
Cyprinus carpio	common carp
Mylocheilus caurinus	peamouth
Ptychocheilus oregonensis	northern pikeminnow
Rhinichthys cataractae	longnose dace
Rhinichthys falcatus	leopard dace
Rhinichthys osculus	speckled dace
Richardsonius balteatus	redside shiner
Livebearers (family Poeciliidae)	
Gambusia affinis	Western mosquitofish
Cods (family Gadidae)	
Lota lota	burbot
Pipefishes, sticklebacks (family Gasterosteidae)	
Gasterosteus aculeatus	threespine stickleback
Pungitius pungitius	ninespine stickleback
Anchovies, herrings (family Clupeidae)	
Alosa sapidissima	American shad
Cyprins, minnows, suckers (family Catostomidae)	
Acrocheilus alutaceus	chiselmouth
Catostomus columbianus	bridgelip sucker
Catostomus macrocheilus	largescale sucker
Catostomus platyrhynchus	mountain sucker
Cyprinus carpio	common carp
Mylocheilus caurinus	peamouth
Ptychocheilus oregonensis	northern pikeminnow
Rhinichthys cataractae	longnose dace
Rhinichthys falcatus	leopard dace

Table C-5 Fish Species Occurring in the Hanford Reach

Scientific Name	Common Name
Rhinichthys osculus	speckled dace
Richardsonius balteatus	redside shiner
Livebearers (family Poeciliidae)	
Gambusia affinis	Western mosquitofish
Cods (family Gadidae)	
Lota lota	burbot
Pipefishes, sticklebacks (family Gasterosteidae)	
Gasterosteus aculeatus	threespine stickleback
Pungitius pungitius	ninespine stickleback
Perch-like fishes (family Centrarchidae)	
Lepomis gibbosus	pumpkinseed
Lepomis macrochirus	bluegill
Micropterus dolomieui	smallmouth bass
Micropterus salmoides	largemouth bass
Perca flavenscens	yellow perch
Pomoxis annularis	white crappie
Pomoxis nigromaculatus	black crappie
Sander vitreus	walleye
Trout perches (family Perocpsidae)	
Percopsis transmontana	sand roller
Lampreys (family Petromyzontidae)	
Lampetra ayresii	river lamprey
Lampetra tridentata	Pacific lamprey
Salmonids, salmons, trouts (family Salmonidae)	
Coregonus clupeaformis	lake whitefish
Oncorhynchus clarkii	cutthroat trout
Oncorhynchus kisutch	coho salmon
Oncorhynchus mykiss	rainbow trout (steelhead)
Oncorhynchus nerka	sockeye salmon
Oncorhynchus tshawytscha	Chinook salmon
Prosopium williamsoni	mountain whitefish
Salvelinus confluentus	bull trout
Salvelinus malma	Dolly Varden
Chabots, sculpins (family Cottidae)	
Cottus asper	prickley sculpin
Cottus bairdii	mottled sculpin

Table C-5 Fish Species Occurring in the Hanford Reach

Scientific Name	Common Name
Cottus beldingii	Piute sculpin
Cottus perplexus	reticulate sculpin
Cottus rhotheus	torrent sculpin
Bullhead catfishes, North American freshwater catfishes (family Ictaluridae)	
Ameiurus melas	black bullhead
Ameiurus natalis	yellow bullhead
Ameiurus nebulosus	brown bullhead
Ictalurus punctatus	channel catfish

Source: Neitzel DA, ed., Bunn AL, Cannon SD, Duncan JP, Fowler RA, and others. 2005. *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev 17, Pacific Northwest National Laboratory, Richland, Washington.

Table C-6 Plant Species of Concern on the Hanford Site

Scientific Name	Common Name	Status	
		Federal	State
Aliciella (= Gilia) leptomeria	Great Basin gilia		T
Allium robinsonii	Robinson's onion		W
Allium scilloides	scilla onion		W
Ammannia robusta	grand redstem		T
Anagallis (= Centunculus)minimus	chaffweed		T
Artemisia lindleyana	Columbia River mugwort		W
Astragalus columbianus	Columbia milkvetch	SC	S
Astragalus conjunctus var. rickardii	basalt milkvetch		W
Astragalus geyeri	Geyer's milkvetch		T
Astragalus sclerocarpus	stalked-pod milkvetch		W
Astragalus speirocarpus	medic milkvetch		W
Astragalus succumbens	crouching milkvetch		W
Balsamorhiza rosea	rosy balsamroot		W
Camissonia (= Oenothera) minor	small-flowered evening-primrose		S
Camissonia (= Oenothera) pygmaea	dwarf evening primrose		S
Carex hystericina	porcupine sedge		W
Castilleja exilis	annual paintbrush		W
Cistanthe (= Calyptridium) roseum	rosy pussypaws		T
Crassula aquatica	pigmy-weed		W
Cryptantha leucophaea	gray cryptantha	SC	S
Cryptantha scoparia	desert cryptantha		S
Cryptantha spiculifera (= C. interrupta)	Snake River cryptantha		S
Cuscuta denticulata	desert dodder		T
Cyperus bipartitus (rivularis)	shining flatsedge		W
Delphinium multiplex	Kittitas larkspur		W
Eatonella nivea	white eatonella		T
Eleocharis rostellata	beaked spike-rush		S
Epipactis gigantea	giant helleborine		W
Erigeron piperianus	Piper's daisy		S
Eriogonum codium	Umtanum desert buckwheat	C	E
Hierchloe odorata =(Anthoxanthm hirtum)	vanilla grass		R1
Hypericum majus	Canadian St. John's wort		S
Limosella acaulis	southern mudwort		W
Lindernia dubia var. anagallidea	false pimpernel		W
Lipocarpha (= Hemicarpha) aristulata	awned halfchaff sedge		T

Table C-6 Plant Species of Concern on the Hanford Site

Scientific Name	Common Name	Status	
		Federal	State
Loeflingia squarrosa var. squarrosa	loeflingia		T
Lomatium tuberosum	Hoover's desert parsley	SC	S
Mimulus suksdorfii	Suksdorf's monkey flower		S
Minuartia pusilla var. pusilla	annual sandwort		R1
Nama densum var. parviflorum	small-flowered nama		W
Nicotiana attenuata	coyote tobacco		S
Oenothera caespitosa	desert evening-primrose		S
Pectocarya penicillata	winged combseed		W
Pectocarya setosa	bristly combseed		W
Pediocactus simpsonii var. robustior =(P. nigrispinus)	hedgehog cactus		R1
Pellaea glabella simplex	smooth cliffbrake		W
Penstemon eriantherus whitedii	fuzzytongue penstemon		S
Physaria (= Lesquerella) tuplashensis	White Bluffs bladderpod	C	T
Rorippa columbiae	Columbia yellowcress	SC	E
Rotala ramosior	lowland toothcup		T

Federal Definitions
(50 CFR 17, Endangered and Threatened Wildlife and Plants, as amended)

Federal Status under the U.S. Endangered Species Act (USESA) as published in the Federal Register:

C = Candidate species. Sufficient information exists to support listing as Endangered or Threatened.

SC = Species of Concern. An unofficial status, the species appears to be in jeopardy, but insufficient information to support listing.

State Definitions
(WSDNR. 2011. Washington Dept. of Natural Resources, Washington Natural Heritage Program, Olympia, WA)

State Status of plant species is determined by the Washington Natural Heritage Program. Factors considered include abundance, occurrence patterns, vulnerability, threats, existing protection, and taxonomic distinctness. Values include:

E = Endangered. In danger of becoming extinct or extirpated from Washington.

T = Threatened. Likely to become Endangered in Washington.

S = Sensitive. Vulnerable or declining and could become Endangered or Threatened in the state.

R1 = Review group 1. Of potential concern but needs more field work to assign another rank.

W = Watch. More abundant and/or less threatened than previously thought.

Source: PNNL. 2010. *Hanford Site Environmental Report for Calendar Year 2009*, PNNL 19455, Pacific Northwest National Laboratory, Richland, Washington.

Table C-7 Wildlife Species of Concern on the Hanford Site

Scientific Name	Common Name	Status	
		Federal	State
Mammals			
Antrozous pallidus	pallid bat		W
Lagurus curtatus	sagebrush vole		W
Lepus californicus	black-tailed jackrabbit		SC
Lepus townsendii	white-tailed jackrabbit		SC
Myotis leibii	small-footed myotis		W
Myotis volans	long-legged myotis		W
Onychomys leucogaster	northern grasshopper mouse		W
Pipistrellus hesperus	western pipistrelle		W
Sorex merriami	Merriam's shrew		SC
Spermophilus townsendii	Townsend's ground squirrel	FCo	SC
Spermophilus washingtoni	Washington ground squirrel[(a)]	FC	SC
Taxidea taxus	badger		W
Birds			
Accipter gentilis	northern goshawk[(a)]	FCo	SC
Aechmophorus clarkii	Clark's grebe		W
Aechmophorus occidentalis	western grebe		SC
Ammodramus savannarum	grasshopper sparrow		W
Amphispiza belli	sage sparrow		SC
Aquila chrysaetos	golden eagle		SC
Ardea alba	great egret		W
Ardea herodias	great blue heron		W
Athene cunicularia	burrowing owl	FCo	SC
Buteo regalis	ferruginous hawk	FCo	ST
Buteo swainsoni	Swainson's hawk		W
Carduelis psaltria	lesser goldfinch		W
Cathartes aura	turkey vulture[(b)]		W
Centrocercus urophasianus	greater sage grouse	FC	ST
Chlidonias niger	black tern[(b)]		W
Contopus cooperi	olive-sided flycatcher	FCo	
Dolichonyx oryzivorus	bobolink[(b)]		W
Empidonax wrightii	gray flycatcher		W
Falco columbarius	merlin		SC
Falco mexicanus	prairie falcon		W

Table C-7 Wildlife Species of Concern on the Hanford Site

Scientific Name	Common Name	Status	
		Federal	State
Falco peregrinus	peregrine falcon	FCo	SS
Falco rusticolus	gyrfalcon[(b)]		W
Gavia immer	common loon		SS
Grus canadensis	sandhill crane		SE
Haliaeetus leucocephalus	bald eagle[(c)]	FCo	SS
Himantopus mexicanus	black-necked stilt		W
Lanius ludovicianus	loggerhead shrike	FCo	SC
Melanerpes lewis	Lewis's woodpecker[(a)]		SC
Myiarchus cinerascens	ash-throated flycatcher[(b)]		W
Numenius americanus	long-billed curlew		W
Nyctea scandiaca	snowy owl		W
Nycticorax nycticorax	black-crowned night-heron		W
Oreoscoptes montanus	sage thrasher		SC
Otus flammeolus	flamulated owl[(a)]		SC
Pandion haliaetus	osprey		W
Pelecanus erythrorhynchos	American white pelican		SE
Podiceps auritus	horned grebe		W
Podiceps grisegena	red-necked grebe[(b)]		W
Sialia mexicana	western bluebird		W
Sterna caspia	Caspian tern		W
Sterna forsteri	Forster's tern		W
Sterna paradisaea	Arctic tern[(b)]		W
Amphibians and Reptiles			
Bufo boreas	western toad	FCo	SC
Bufo woodhousii	Woodhouse's toad		W
Hypsiglena torquata	night snake		W
Masticophis taeniatus	striped whipsnake		SC
Phrynosoma douglassii	short-horned lizard		W
Sceloporus graciosus	sagebrush lizard	FCo	SC
Fish			
Catastomus platyrhynchus	mountain sucker[(a)]		SC
Cottus beldingi	piute sculpin		W
Cottus perplexus	reticulate sculpin		W
Lampetra ayresi	river lamprey[(a)]	FCo	SC

Table C-7 Wildlife Species of Concern on the Hanford Site

Scientific Name	Common Name	Status	
		Federal	State
Lampetra tridentata	Pacific lamprey	FCo	W
Oncorhynchus mykiss	steelhead	FT	SC
Oncorhynchus tshawytscha	spring-run Chinook salmon	FE	SC
Percopsis transmontana	sand roller		W
Rhinichthys flacatus	leopard dace[a]		SC
Salvelinus confluentus	bull trout[a]	FT	SC
Mollusks			
Anodonta californiensis	California floater	FCo	SC
Anodonta kennerlyi	western floater		W
Anodonta oregonensis	Oregon floater		W
Fisherola nuttalli	shortfaced lanx		SC
Fluminicola columbiana	great Columbia River spire snail	FCo	SC
Margaritifera falcata	western pearlshell		W
Insects			
Boloria selene atrocostalis	silver-bordered fritillary		SC
Callophrys sheridanii neoperplexa	canyon green hairstreak		W
Chlosyne palla palla	northern checkerspot		W
Cicindela columbica	Columbia River tiger beetle[a]		SC
Epargyreus clarus californicus	silver-spotted skipper		W
Erynnis persius	Persius' duskywing		W
Harkenclenus titus immaculosus	coral hairstreak		W
Hesperia juba	juba skipper		W
Hesperia nevada	Nevada skipper		W
Limenitis archippus lahontani	viceroy		W
Lycaena helloides	purplish copper		W
Lycaena rubida perkinsorum	ruddy copper		W
Ochlodes sylvanoides bonnevilla	Bonneville skipper		W
Phyciodes cocyta pascoensis	Pasco pearl		W

Table C-7 Wildlife Species of Concern on the Hanford Site

Scientific Name	Common Name	Status	
		Federal	State

Federal Definitions
(from *Endangered Species Act*, Public Law 93-205, as amended).

FC = Federal candidate: A species that that is identified for listing as a federally protected species under the Endangered Species Act. These species are not currently under federal protection but are being considered for inclusion if the scientific data supports listing.

FE = Federal endangered: A species in danger of extinction or extirpation throughout all or a substantial portion of its range.

FT = Federal threatened: A species that is likely to become endangered within the near future because of threats to its population.

FCo = Species of Concern: species about which there are concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act.

State Definitions
(WSDNR. 2011. Washington Dept. of Natural Resources, Washington Natural Heritage Program, Olympia, WA)

Defined in WAC 232-12-297.

SC = State candidate: A wildlife species native to Washington State that the Department of Wildlife (WDFW) will review for possible listing as endangered, threatened, or sensitive. Candidate species are defined in WDFW Policy M-6001.

SE = State endangered: A species native to Washington State that is seriously threatened with extinction throughout all or a substantial portion of its range within the state. Endangered species are designated in WAC 232-12-014.

SS = State sensitive: A wildlife species native to the state of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats. Sensitive species are designated in WAC 232-12-011.

ST = State threatened: A species native to Washington State likely to become endangered within the foreseeable future throughout substantial portions of its range within the state without cooperative management or the removal of threats. Threatened species are designated in WAC 232-12-011.

W = Watch list species: Taxa that are more abundant and/or less threatened than previously assumed.

Notes:
(a) Probable, but not observed, on the Hanford Site.
(b) Reported, but seldom observed on the Hanford Site.
(c) Removed from the list of threatened wildlife effective August 8, 2007 (72 FR 37346).

Source: PNNL. 2010. *Hanford Site Environmental Report for Calendar Year 2009*, PNNL 19455, Pacific Northwest National Laboratory, Richland, Washington.

Supplement 1

Constituents of Potential Concern for the WTP Air and Dangerous Waste Permits (24590-WTP-RPT-ENV-10-001)

Provided under separate cover.

Supplement 2

Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant (24590-WTP-RPT-PO-03-008)

Provided under separate cover.

Supplement 3

Estimated Organic Emissions from Process Cells (24590-WTP-HAC-50-00001)

Provided under separate cover.

Supplement 4

Chemical Parameters and Toxicological Inputs for the Environmental Risk Assessment for the Hanford Tank Waste Treatment and Immobilization Plant (24590-WTP-RPT-ENV-14-003)

Provided under separate cover.

Supplement 5

Hanford Tank Waste Treatment and Immobilization Plant Risk Assessment Air Quality Modeling Protocol (24590-WTP-RPT-ENV-08-001)

Provided under separate cover.

R50005384

Document title:	**Constituents of Potential Concern for the WTP Air and Dangerous Waste Permits**
Document number:	24590-WTP-RPT-ENV-10-001, Rev 0

Contract number:	DE-AC27-01RV14136
Department:	Environmental and Nuclear Safety
Author(s):	L Bostic
Checked by:	D Blumenkranz D. Blumenkranz
Issue status:	Approved

Approved by:	B Erlandson
Approver's position:	Environmental Manager
Approver's signature:	*Signature* 2-8-11 *Date*

River Protection Project
Waste Treatment Plant
2435 Stevens Center Place
Richland, WA 99354
United States of America
Tel: 509 371 2000

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA) are regulated at the U. S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts that pursuant to AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

History Sheet

Rev	Reason for revision	Revised by
0	Initial issue.	L Bostic

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Acronyms

BBI	best basis inventory
BNI	Bechtel National, Inc.
CAS	Chemical Abstracts Registry Service
CCN	correspondence control number
CFR	Code of Federal Regulations
CHG	CH2M HILL Hanford Group, Inc.
COPC	chemical of potential concern
DQO	data quality objective
DST	double shell tank
DOE	US Department of Energy
RDQO	*Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project* (Wiemers and others 1998)
DQO	data quality objectives
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
HHRAP	Human Health Risk Assessment Protocol
HLW	high-level waste
IRIS	Integrated Risk Information System
LAW	low-activity waste
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PIC	product of incomplete combustion
PRA	pre-demonstration test risk assessment
RDQO	regulatory data quality objective
ROPC	radionuclide of potential concern
SST	single shell tank
TAP	toxic air pollutant
TWINS	Tank Waste Information Network System
UHC	underlying hazardous constituent
UTS	universal treatment standard
VSL	Vitreous State Laboratory of the Catholic University of America
WAC	Washington Administrative Code
WSPS	Waste Stream Profile Sheet
WTP	Hanford Tank Waste Treatment and Immobilization Plant

Executive Summary

This report identifies the list of constituents of potential concern that will be used for input to the Hanford Tank Waste Treatment and Immobilization Plant (WTP) environmental air permits and the dangerous waste permit environmental risk assessment. Chemicals of potential concern (COPC), radionuclides of potential concern (ROPC), and constituents possessing both radioactive and non-radioactive effects are addressed. Sources of information include the *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project* (Wiemers and others 1998), produced by Pacific Northwest National Laboratory, as modified by the subsequent *Regulatory Data Quality Objectives Optimization Report* (BNI 2004); COPCs identified by the CH2M HILL Hanford Group, Inc.; COPCs added as a result of an update to the toxic air permit regulations (WAC 171-460); COPCs added as a result of updates to the underlying hazardous constituents (UHC), universal treatment standards (UTS) (40 CFR 268.48), and Double Shell Tank (DST) Part A (Ecology 2008); COPCs added at the request of the Washington State Department of Ecology (Ecology) and the US Environmental Protection Agency (EPA); EPA Products of Incomplete Combustion (PIC); COPCs detected during research and testing of scale model vitrification units by the Catholic University of America, Vitreous State Laboratory (VSL); and radionuclides of potential concern identified in the Hanford underground tanks in *Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes* (Kupfer and others 1997).

The resulting list of compounds totals 363 COPCs and 46 ROPCs, including 11 compounds that will be evaluated for radioactive and non-radioactive effects.

1 Introduction

Hanford tank waste consists of approximately 54 million US gallons (204 million liters) of radioactive and mixed dangerous wastes stored in underground tanks at the US Department of Energy's (DOE) Hanford Site. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being constructed to treat mixed waste from the underground storage tanks. After the tank waste is received at the WTP from the Hanford Site double-shell tank system, it will be pretreated and then immobilized using a process called vitrification. Vitrification is a thermal process that converts the waste materials into a durable glass. The vitrified wastes and secondary wastes resulting from the WTP processes will be transferred to permitted treatment, storage, or disposal units for disposition. Offgas generated by the pretreatment and vitrification processes will be treated in independent systems. Details of the WTP system design are provided in Chapter 4, of the *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste*, Part III, Operating Unit 10 (Ecology 2009).

This report documents the process for identifying the constituents of potential concern that will be used for input to the WTP environmental air permits and dangerous waste permit environmental risk assessment. The process identifies chemicals of potential concern (COPC) and radionuclides of potential concern (ROPC). The process results in 363 COPCs and 46 ROPCs, including 11 compounds that will be evaluated for radioactive and non-radioactive effects (Table 1-1). The table is organized by Chemical Abstracts Registry Service (CAS) number to aid the search for a particular COPC.

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
100-02-7	p-Nitrophenol
100-21-0	Phthalic acid
100-25-4	1,4-Dinitrobenzene
10028-15-6	Ozone
10028-17-8	Tritium
100-40-3	4-Ethenylcyclohexene
100-41-4	Ethyl benzene
100-42-5	Styrene
100-44-7	Benzyl chloride
10045-97-3	Cesium-137
100-47-0	Benzonitrile
100-51-6	Benzyl alcohol
100-52-7	Benzaldehyde
10061-01-5	cis-1,3-Dichloropropene
10061-02-6	trans-1,3-Dichloropropene
10098-91-6	Yttrium-90
10098-97-2	Strontium-90
10102-44-0	Nitrogen dioxide
101-55-3	4-Bromophenylphenyl ether
101-77-9	4,4-Methylenedianiline
10198-40-0	Cobalt-60
103-33-3	Azobenzene
103-65-1	n-Propyl benzene (Isocumene)
104-51-8	n-Butylbenzene
104-76-7	2-Ethyl-1-hexanol
105-67-9	2,4-Dimethylphenol
10595-95-6	n-Nitrosomethylethylamine
106-43-4	4-Chlorotoluene (p-Tolyl chloride)
106-44-5	p-Cresol (4-methyl phenol)
106-46-7	1,4-Dichlorobenzene
106-47-8	p-Chloroaniline
106-49-0	p-Toluidine
106-51-4	Quinone
106-88-7	1,2-Epoxybutane
106-89-8	Epichlorohydrin (1-chloro-2,3 epoxypropane)
106-93-4	Ethylene dibromide
106-99-0	1,3-Butadiene
107-02-8	Acrolein
107-05-1	3-Chloropropene
107-06-2	1,2-Dichloroethane
107-12-0	Propionitrile
107-13-1	Acrylonitrile
107-19-7	Propargyl alcohol

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
107-21-1	Ethylene glycol (1,2-ethanediol)
107-98-2	Propylene glycol monomethyl ether
108-05-4	Acetic acid vinyl ester
108-10-1	4-Methyl-2-pentanone
108-39-4	m-Cresol
108-60-1	bis (2-Chloroisopropyl)ether
108-67-8	1,3,5-Trimethylbenzene
108-86-1	Bromobenzene (Phenyl bromide)
108-87-2	Methylcyclohexane
108-88-3	Toluene
108-90-7	Chlorobenzene
108-94-1	Cyclohexanone
108-95-2	Phenol
109-74-0	n-Butanenitrile
109-75-1	3-Butenenitrile
109-77-3	Malononitrile
109-86-4	2-Methoxyethanol
109-99-9	Tetrahydrofuran
110-00-9	Furan
110-54-3	n-Hexane
110-59-8	Pentanenitrile
110-80-5	2-Ethoxyethanol
110-82-7	Cyclohexane
110-83-8	Cyclohexene
110-86-1	Pyridine
111-15-9	Ethylene glycol monoethyl ether acetate
111-44-4	bis(2-Chloroethyl)ether
111-65-9	n-Octane
111-76-2	2-Butoxyethanol
111-84-2	n-Nonane
111-91-1	bis(2-Chloroethoxy)methane
1120-21-4	Undecane
1120-71-4	1,3-Propane sultone
112-30-1	1-Decanol
112-31-2	Decanal
112-40-3	Dodecane
117-81-7	Bis(2-ethylhexyl) phthalate
117-84-0	Di-n-octylphthalate
118-74-1	Hexachlorobenzene
119-90-4	3,3'-Dimethoxybenzidine
120-12-7	Anthracene
120-82-1	1,2,4-Trichlorobenzene
120-83-2	2,4-Dichlorophenol
121-14-2	2,4-Dinitrotoluene

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
122-39-4	N,N-Diphenylamine
122-66-7	1,2-Diphenylhydrazine
123-33-1	Maleic hydrazide
123-38-6	Propionaldehyde
123-72-8	Butanal
123-91-1	1,4-Dioxan
124-18-5	Decane
124-38-9	Carbon dioxide
124-48-1	Chlorodibromomethane
126-73-8	Tributyl phosphate
126-98-7	2-Methyl-2-propenenitrile
127-18-4	1,1,2,2-Tetrachloroethene
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol
129-00-0	Pyrene
131-11-3	Dimethyl Phthalate
131-89-5	2-Cycloyhexyl-4,6-dinitrophenol
132-64-9	Dibenzofuran
1330-20-7	Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations)
133-06-2	Captan
1336-36-3	Polychlorinated biphenyls (209 congeners)
134-32-7	alpha-Naphthylamine
135-98-8	sec-Butylbenzene
13966-29-5	Uranium-234
13967-48-1	Ruthenium-106
13967-70-9	Cesium-134
13968-55-3	Uranium-233
13981-15-2	Curium-244
13981-16-3	Plutonium-238
13981-37-8	Nickel-63
13982-10-0	Plutonium-242
13982-63-3	Radium-226
13982-70-2	Uranium-236
13994-20-2	Neptunium-237
14119-32-5	Plutonium-241
14119-33-6	Plutonium-240
14133-76-7	Technetium-99
14158-29-3	Uranium-232
141-78-6	Acetic acid ethyl ester
14234-35-6	Antimony-125
14265-44-2	Phosphate
14331-85-2	Protactinium-231
14336-70-0	Nickel-59
14391-16-3	Europium-155
145-73-3	Endothall

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
14596-10-2	Americium-241
14683-23-9	Europium-152
14762-75-5	Carbon-14
14797-55-8	Nitrate
14797-65-0	Nitrite
14808-79-8	Sulfate
14952-40-0	Actinium-227
14993-75-0	Americium-243
15046-84-1	Iodine-129
15117-48-3	Plutonium-239
15117-96-1	Uranium-235
15262-20-1	Radium-228
15510-73-3	Curium-242
15585-10-1	Europium-154
15594-54-4	Thorium-229
156-59-2	cis-1,2-Dichloroethene
156-60-5	1,2-trans-Dichloroethene
15715-94-3	Samarium-151
15751-77-6	Zirconium-93
15757-87-6	Curium-243
15758-45-9	Selenium-79
15832-50-5	Tin-126
1634-04-4	Methyl tert-butyl ether
16887-00-6	Chloride
16984-48-8	Fluoride
1746-01-6	2,3,7,8-Tetrachlorodibenzo(p)dioxin (TCDD)
189-55-9	Dibenzo[a,i]pyrene
189-64-0	Dibenzo[a,h]pyrene
191-24-2	Benzo(g,h,i)perylene
191-30-0	Dibenzo(a,l)pyrene
192-65-4	Dibenzo[a,e]pyrene
192-97-2	Benzo(e)pyrene
193-39-5	Indeno(1,2,3-cd)pyrene
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin
205-82-3	Benzo[j]fluoranthene
205-99-2	Benzo(b)fluoranthene
206-44-0	Fluoranthene
207-08-9	Benzo(k)fluoranthene
208-96-8	Acenaphthylene
218-01-9	Chrysene
224-42-0	Dibenz[a,j]acridine
2245-38-7	2,3,5-Trimethylnaphthalene
226-36-8	Dibenz[a,h]acridine
22967-92-6	Methyl mercury

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
23950-58-5	Pronamide
24959-67-9	Bromide
27154-33-2	Trichlorofluoroethane
31508-00-6	2,3',4,4',5-Pentachlorobiphenyl (PCB 118)
319-84-6	alpha-BHC
319-85-7	beta-BHC
32598-13-3	3,3',4,4'-Tetrachlorobiphenyl (PCB 77)
32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)
3268-87-9	Octachlorodibenzo(p)dioxin
32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin
3697-24-3	5-Methylchrysene
378253-40-8	Barium-137m
378253-44-2	Cadmium-113m
378782-82-2	Niobium-93m
38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)
39001-02-0	Octachlorodibenzofuran
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin
39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)
40321-76-4	1,2,3,7,8-Pentachlorodibenzo(p)dioxin
4170-30-3	Crotonaldehyde (Propylene aldehyde)
41851-50-7	Chlorocyclopentadiene
460-19-5	Cyanogen (oxalonitrile)
4786-20-3	2-Butenenitrile
50-00-0	Formaldehyde
50-32-8	Benzo(a)pyrene
506-68-3	Cyanogen bromide (bromocyanide)
506-77-4	Cyanogen chloride
510-15-6	Chlorobenzilate
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran
51-28-5	2,4-Dinitrophenol
51-79-6	Ethyl carbamate (urethane)
52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)
528-29-0	1,2-Dinitrobenzene (o-Dinitrobenzene)
532-27-4	2-Chloroacetophenone
534-52-1	4,6-Dinitro-o-cresol
53-70-3	Dibenz[a,h]anthracene
5385-75-1	Dibenzo(a,e)fluoranthene
540-59-0	1,2-Dichloroethene (total) (1,2-Dichloroethylene)
540-73-8	1,2-Dimethylhydrazine
540-84-1	2,2,4-Trimethylpentane
541-73-1	1,3-Dichlorobenzene
542-75-6	1,3-Dichloropropene
542-88-1	bis(Chloromethyl)ether

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran
56-23-5	Carbon tetrachloride
56-49-5	3-Methylcholanthrene
56-55-3	Benzo(a)anthracene
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran
57-12-5	Cyanide
57-24-9	Strychnine
57465-28-8	3,3',4,4',5-Pentachlorobiphenyl (PCB 126)
57653-85-7	1,2,3,6,7,8,-Hexachlorodibenzo(p)dioxin
57-74-9	Chlordane
581-42-0	2,6-Dimethylnaphthalene
584-84-9	2,4-Toluene diisocyanate
58-89-9	gamma-BHC (Lindane)
58-90-2	2,3,4,6-Tetrachlorophenol
589-38-8	3-Hexanone
591-50-4	Benzene, iodo-
591-78-6	2-Hexanone
593-60-2	Bromoethene (Vinyl bromide)
593-74-8	Dimethyl Mercury
59-50-7	4-Chloro-3-methylphenol
59-89-2	N-Nitrosomorpholine
60-11-7	Dimethyl aminoazobenzene
602-87-9	5-Nitroacenaphthene
60-29-7	Ethyl ether
60-35-5	Acetamide
606-20-2	2,6-Dinitrotoluene
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran
608-93-5	Pentachlorobenzene
61626-71-9	Dichloropentadiene
621-64-7	N-Nitroso-di-n-propylamine
624-83-9	Methyl isocyanate
62-50-0	Ethyl methanesulfonate
62-53-3	Aniline
62-75-9	N-Nitroso-N,N-dimethylamine
628-73-9	Hexanenitrile
630-08-0	Carbon monoxide [e]
630-20-6	1,1,1,2-Tetrachloroethane
64-18-6	Formic acid (methanoic acid)
65510-44-3	2',3,4,4',5-Pentachlorobiphenyl (PCB 123)
65-85-0	Benzoic acid
67-56-1	Methyl alcohol
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
67-63-0	2-Propyl alcohol
67-64-1	2-Propanone (Acetone)
67-66-3	Chloroform
67-72-1	Hexachloroethane
69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)
70-30-4	Hexachlorophene
70362-50-4	3,4,4',5-Tetrachlorobiphenyl (PCB 81)
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran
71-36-3	n-Butyl alcohol
71-43-2	Benzene
71-55-6	1,1,1-Trichloroethane
72-43-5	Methoxychlor
72-55-9	4,4-DDE
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran
7429-90-5	Aluminum
7439-89-6	Iron
7439-92-1	Lead
7439-93-2	Lithium
7439-95-4	Magnesium
7439-96-5	Manganese
7439-97-6	Mercury
7439-98-7	Molybdenum
7440-02-0	Nickel
7440-16-6	Rhodium
7440-22-4	Silver
7440-23-5	Sodium
7440-24-6	Strontium (total)
7440-25-7	Tantalum
7440-28-0	Thallium
7440-29-1	Thorium-232
7440-31-5	Tin
7440-33-7	Tungsten
7440-36-0	Antimony
7440-38-2	Arsenic
7440-39-3	Barium
7440-41-7	Beryllium
7440-43-9	Cadmium
7440-47-3	Chromium
7440-48-4	Cobalt
7440-50-8	Copper
7440-61-1	Uranium
7440-61-1R	Uranium-238 [d]
7440-62-2	Vanadium
7440-65-5	Yttrium

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
7440-66-6	Zinc
7440-67-7	Zirconium
7446-09-5	Sulfur dioxide
74472-37-0	2,3,4,4',5-Pentachlorobiphenyl (PCB 114)
74-83-9	Bromomethane
74-87-3	Chloromethane
74-88-4	Iodomethane
74-95-3	Methylene bromide
74-97-5	Bromochloromethane
75-00-3	Chloroethane
75-01-4	1-Chloroethene
75-02-5	Fluoroethene (vinyl fluoride)
75-05-8	Acetonitrile
75-07-0	Acetaldehyde
75-09-2	Dichloromethane (Methylene Chloride)
75-15-0	Carbon disulfide
75-21-8	Ethylene oxide (Oxirane)
75-25-2	Bromoform
75-27-4	Bromodichloromethane
75-29-6	2-Chloropropane
75-34-3	1,1-Dichloroethane
75-35-4	1,1-Dichloroethene
75-44-5	Phosgene (hydrogen phosphide)
75-45-6	Chlorodifluoromethane
75-50-3	Trimethylamine
75-69-4	Trichlorofluoromethane
75-71-8	Dichlorodifluoromethane
76-01-7	Pentachloroethane
76-13-1	1,2,2-Trichlorotrifluoroethane
764-41-0	1,4-Dichloro-2-butene
76-44-8	Heptachlor
7647-01-0	Hydrogen chloride
765-34-4	Glycidylaldehyde
7664-39-3	Hydrogen Fluoride
7664-41-7	Ammonia/Ammonium
7704-34-9	Total Sulfur (thermodynamically stable)
7723-14-0	Phosphorus
77-47-4	Hexachlorocyclopentadiene
77-78-1	Dimethyl sulfate
7782-41-4	Fluorine gas F2
7782-49-2	Selenium
7782-50-5	Chlorine
78-83-1	2-Methylpropyl alcohol
78-87-5	1,2-Dichloropropane

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
78-93-3	2-Butanone
79-00-5	1,1,2-Trichloroethane
79-01-6	1,1,2-Trichloroethylene
79-10-7	2-Propenoic acid
79-34-5	1,1,2,2-Tetrachloroethane
79-46-9	2-Nitropropane
80-62-6	Methyl methacrylate
822-06-0	Hexamethylene-1,5-diisocyanate
823-40-5	Toluene-2,6-diamine
82-68-8	Pentachloronitrobenzene (PCNB)
832-69-9	1-Methylphenanthrene
83-32-9	Acenaphthene
84-66-2	Diethyl phthalate
84-74-2	Di-n-butylphthalate
85-01-8	Phenanthrene
85-44-9	Phthalic anhydride (1,2-benzenedicarboxylic anhydride)
85-68-7	Butylbenzylphthalate
86-73-7	Fluorene
87-61-6	1,2,3-Trichlorobenzene
87-68-3	Hexachlorobutadiene
87-86-5	Pentachlorophenol
88-06-2	2,4,6-Trichlorophenol
88-74-4	o-Nitroaniline (2-nitroaniline)
88-75-5	2-Nitrophenol
90-04-0	o-Anisidine
90-12-0	1-Methylnaphthalene
91-20-3	Naphthalene
91-22-5	Quinoline
91-57-6	2-Methylnaphthalene
91-58-7	2-Chloronaphthalene
91-94-1	3,3'-Dichlorobenzidine
924-16-3	N-Nitroso-di-n-Buetylamine
92-52-4	1,1`-Biphenyl
94-59-7	Safrole (5-(2-Propenyl)-1,3-benzodioxole)
94-75-7	2,4-D
95-48-7	o-Cresol
95-49-8	o-Chlorotoluene
95-50-1	1,2-Dichlorobenzene
95-53-4	o-Toluidine
95-57-8	2-Chlorophenol
95-63-6	1,2,4-Trimethyl benzene
95-94-3	1,2,4,5-Tetrachlorobenzene
95-95-4	2,4,5-Trichlorophenol
96-12-8	1,2-Dibromo-3-chloropropane

Table 1-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent
96-18-4	1,2,3-Trichloropropane
96-45-7	Ethylene thiourea
97-63-2	Ethyl methacrylate
98-01-1	Furfural
98-06-6	tert-Butyl benzene
98-07-7	Benzotrichloride
98-82-8	Cumene
98-83-9	Methyl styrene (mixed isomers)
98-86-2	Acetophenone
98-95-3	Nitrobenzene
99-35-4	1,3,5-Trinitrobenzene
99-65-0	1,3-Dinitrobenzene
99-87-6	p-Cymene
N/A	Particulate matter

2 WTP Constituents of Potential Concern

The selection process for COPCs and ROPCs for the WTP focused on compounds that are: (1) likely to be emitted due to the presence of the compound or its precursors in the waste feed; (2) potential products of incomplete combustion (PIC); and/or (3) those compounds potentially toxic to humans.

The process of identifying COPCs and ROPCs that are potentially emitted from the WTP due to the presence of the compound or its precursors in the waste feed, or are potentially formed as products of incomplete combustion, includes the following ten sequential steps:

1. Start with the list of chemicals potentially present in the waste. This list was taken from the *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project* (Wiemers and others 1998), also referred to as the "regulatory data quality objectives (RDQO)." The starting list includes both organic and inorganic constituents (Section 2.1.1).
2. Add lower-toxicity organic chemicals that may be present in the tank waste but were excluded from the RDQO list (Section 2.1.2).
3. Update the organic RDQO input list with changes to the Underlying Hazardous Constituents (UHC)/ Universal Treatment Standards (UTS) and add tank waste compounds identified by the Tank Waste Information Network System (TWINS) or Best Basis Inventory (BBI) not selected as RDQO or low-toxicity additions to the WTP feed COPC list (Section 2.1.3).
4. Add chemicals from the *Industrial Hygiene Chemical Vapor Technical Basis* program (CHG 2004) that were not already included in the COPC list as a result of the steps outlined above (Section 2.1.4).
5. Add radionuclides from Hanford Site tank waste inventory estimates (*Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes* (Kupfer and others 1997, Section 2.1.5).
6. Adjust the list of feed COPCs in accordance with the revision to WAC 173-460 list of toxic air pollutants (TAP) (Section 2.2).
7. Adjust the list of COPCs in accordance with the agreements documented in 24590-WTP-RPT-MGT-04-001, *Regulatory Data Quality Objectives Optimization Report* (BNI 2004) (Section 2.3).
8. Add stack emission compounds from revised WAC 173-460 TAPs list (Section 2.4.2).
9. Add criteria pollutants (Section 2.4.3).
10. Add stack emissions chemicals that EPA has identified as potential PICs in combustion devices (Section 2.4.4).
11. Add chemicals that WTP has identified as site-specific PICs in vitrification unit testing (Section 2.4.5).
12. Adjust list of constituents of potential concern in accordance with agreements reached with the EPA and Ecology (Section 2.5).

Table 2-1 presents the consolidated list of COPCs and ROPCs (organized by source) to be used in the air and dangerous waste permitting activities. The table is coded to provide the source of the compound, identify whether it is a PIC, and identify those compounds that will be evaluated for both radioactive and non-radioactive effects in the permitting activities. Table 2-2 tracks changes to the constituents of potential concern and identifies the reason for changes as the evaluation described in this report proceeds through the COPC identification process.

2.1 COPCs Identified by Hanford Tank Characterization Programs

The process for selecting constituents of potential concern includes the examination of constituents in the waste feed and constituents in the offgas that result from the treatment of the feed. The discussion below describes the process used to determine the appropriate COPCs in the feed using historical tank characterization data. Steps 1 through 4 above identified organic and inorganic waste feed COPCs, and ROPCs. Compounds evaluated for both radioactive and non-radioactive impacts (Section 2, Step 12) are discussed in Section 2.5.4.

2.1.1 COPCs Identified by the Regulatory Data Quality Objectives

The DOE initiated a process to identify Hanford tank waste characterization needs for the proposed Hanford tank waste treatment processes. The RDOQ (Wiemers and others 1998) documents those data needs. The RDQO identified both organic and inorganic compounds to be characterized in tank waste prior to WTP processing. The compounds identified in the RDQO served as the starting list for the WTP COPC list. The following subsections discuss the organic and inorganic COPCs identified that could be potentially emitted from the WTP due to the presence of the compound or its precursors in the waste feed (Section 2, Step 1).

2.1.1.1 Organic COPCs Identified by the Regulatory Data Quality Objectives

The RDQO (Wiemers and others 1998) process for identifying the WTP organic COPCs is described in Appendix A. The process summarized in Appendix A results in a starting list of 125 organic compounds.

2.1.1.2 Inorganic COPCs Identified by the Regulatory Data Quality Objectives

The starting list of inorganics was also established using the RDQO process (Appendix A). The RDQO identified 52 inorganic COPCs. However, the RDQO excluded analyses for four COPCs (cesium, platinum, sulfides, and sulfite), which reduced the number of inorganic COPCs to 48. The excluded compounds are listed in Table 2-2, (adjustment code 1).

2.1.2 Lower Toxicity Organic Chemicals Screened by the Regulatory DQO Process - Added Back to the COPC List

During the RDQO process (Wiemers and others 1998), 217 COPCs were identified as lower toxicity compounds. These compounds were categorized by whether Hanford tank sampling and analysis programs had detected them in the waste or vapor space. Of these lower toxicity constituents, 106 were retained as part of the 125 constituents resulting from the RDQO process. The remaining 111 lower toxicity constituents were removed from further consideration.

Ecology and EPA (CCN 011395) did not agree with the removal of organic chemicals from the COPC list based on toxicity. Therefore, organic chemicals removed by the RDQO due to low toxicity were added to the list of preliminary COPCs (Section 2, Step 2), increasing the number of organic feed COPCs from 125 to 236. These 111 additional low-toxicity chemicals are described in Appendix A.

2.1.3 Updates to the UHC/UTS and DST Part A Organic Inputs to the Regulatory DQO Process

Since the RDQO was completed in 1998, several additions and deletions have been made to the UHC/UTS lists of regulated constituents and Double Shell Tank Dangerous Waste Permit Application Part A Form (Ecology 2008, herein referred to as the DST Part A) constituents. The current list of UHC/UTS and DST Part A constituents is provided in Appendix A, Table A-4. The updated UHC/UTS and DST Part A constituents was compared to the list of compounds identified in TWINS or BBI (Table A-4). The comparison identified five compounds listed as UHC/UTS or DST Part A constituents detected in Hanford tank waste and listed in TWINS or BBI that were not previously identified as COPCs by Section 2, steps 1 and 2 above; these were added to the WTP feed COPC list (Table 2-1, source code 4). Two compounds were dropped from regulation by the updates. However, these two compounds are also listed as toxic air pollutants (TAP); consequently, they were retained for further evaluation as TAPs in Section 2, step 6. Appendix A provides more details of the UHC/UTS, and DST Part A update evaluation. The subsequent steps described below were implemented to evaluate and modify the list of WTP COPCs derived from the RDQO, the lower toxicity constituents added back by agreement with the regulatory agencies, and the updates to the UHC/UTS and DST Part A constituent lists.

2.1.4 COPCs Identified by CH2M Hill Hanford Group Industrial Hygiene Chemical Vapor Program

In October 2004, CH2M HILL Hanford Group (CHG) published a technical basis for the *Industrial Hygiene Chemical Vapor Program* (CHG 2004) to support the management of Hanford tank farms (Section 2, Step 4). The report summarizes the results of the tank farm headspace sampling program and the evaluation of the potential toxicity of headspace compounds. It identifies constituents that are of interest from an industrial hygiene and worker safety perspective. This process identified 52 compounds as constituents of potential concern from a risk assessment and air permitting perspective. A brief summary of the CHG data compilation is provided in Appendix B.

Seventeen compounds were identified that were not otherwise included as COPCs from the processes described above (Section 2, Steps 1-3). Twelve compounds are organic and five are inorganic[1] (see Appendix B, Table B-1). Table 2-1 documents the COPCs from the CHG evaluation (source codes 5, 6, and 9). However, in the evaluation of TAPs (step 6), three additional constituents (for a total of 20 COPCs) were added to the CHG vapor study list following removal (see Section 2.1.4.1) in the evaluation of changes to the TAPs list (Section 2.2.2)[2].

2.1.4.1 Organic COPCs Identified by CH2M Hill Hanford Group Industrial Hygiene Chemical Vapor Program

Twelve organic compounds were identified in the CHG vapor study. Unless there are compelling reasons to the contrary, organic COPCs identified from the vapor program are assumed to represent tank waste (as opposed to waste decomposition byproducts in the vapor space). These 12 compounds were added to the waste feed COPC list. The evaluation of CHG vapor study data returned two mixtures (aroclors mixtures

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[1] Nitrous oxide (CAS No. 10024-97-2) is not shown in Table 2-1, refer to Section 2.1.4.2.

[2] Methyl isocyanate (CAS No. 624-83-9) was also detected in the CHG vapor study, but removed from regulation in the TAPs revision, it was later added as a stack emission COPC due to its presence as an EPA PIC (see Section 2.4.4).

of PCBs) to the WTP COPC feed list that were eliminated in the UHC/UTS, DST Part A review. The aroclors are later removed as discussed in sections 2.3.1.1 and 2.5.1.2.

Three constituents, methylhydrazine (CAS No. 60-34-4), trimethylamine (CAS 75-50-3), and 1,1'-biphenyl (CAS No. 92-52-4) appear on the CHG vapor study list (Appendix B, Table B-1). These constituents were previously identified as COPCs because of their inclusion in the RDQO or list of low-toxicity constituents (due solely to their inclusion as class B TAPs), but were candidates for removal in the TAPs evaluation because they were excluded as TAPs in the revision to the statute; see Appendix C, Table C-4, disposition 2 and 6. However, because CHG identified these constituents in the tank vapor space, they are assumed to represent tank waste. Consequently, they are retained as COPCs and the source code of 5 was assigned in Table 2-1 identifying the CHG vapor study as the source. Methyl isocyanate (CAS No. 624-83-9) was also detected in the CHG vapor study, but removed from regulation in the TAPs revision and deemed reactive (and not detectable in a waste matrix) in the RDQO optimization effort (see Section 2.3.1.1); it was later added as a stack emission COPC due to its presence as an EPA PIC (see Section 2.4.4).

Table 2-2 (adjustment codes 9 and 10) lists the changes and Table 2-1 (source code 5) identifies the WTP organic feed COPCs where the CHG vapor study is the rationale for COPC selection.

2.1.4.2 Inorganic COPCs Identified by CH2M Hill Hanford Group Industrial Hygiene Chemical Vapor Program

Five constituents, nitrous oxide (CAS No. 10024-97-2), nitrogen dioxide (CAS No. 10102-44-0), carbon dioxide (CAS No. 124-38-9), carbon monoxide (CAS No. 630-08-0), and dimethyl mercury (CAS No. 593-74-8) were identified by CHG as present in Hanford tank vapor headspace. Dimethyl mercury is an organo-metallic compound that exhibits characteristics of both organic and inorganic chemicals. It likely is formed from a reaction between elemental mercury and organic constituents in the tank waste. Dimethyl mercury was added as a WTP feed COPC (Table 2-1 source code 6).

CHG identified three gaseous compounds in the vapor headspace, nitrogen dioxide, carbon monoxide and carbon dioxide. They are more appropriately measured in stack emissions (Section 2.4.1).

Nitrous oxide (CAS No. 10024-97-2) was also identified in the CHG vapor program. Nitrous oxide is likely released from the high salt wastes stored in the Hanford tanks which contain higher concentrations of nitrate and nitrite ions. These nitrate and nitrite ions will be analyzed as part of the waste processing at the WTP. Emissions of oxides of nitrogen will be monitored by the WTP during testing and operations as part of the air permitting activities. Analysis for nitrous oxide will not offer additional useful data for managing the waste. Therefore, this COPC was removed from further consideration.

Table 2-1 (source codes 6 and 9) lists the inorganic additions to the COPC list and Table 2-2 (adjustment code 2) lists the deletion.

2.1.5 Radionuclides of Potential Concern

The ROPCs identified in Section 2, Step 4, are discussed in this section. In 1997, Kupfer and others published *Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes*. The report provided a global best-basis inventory estimate of the chemical and radionuclide components of the 177 single- and double-shell underground waste storage tanks on the Hanford Site that will serve as feed to the WTP. Since the RDQO process identified the chemical components of the WTP waste feed, this report was used to develop the ROPC list only. The 46 ROPCs identified represent over 99 percent of the activity of the Hanford tank waste. No screening to reduce the number of ROPCs identified was conducted. Table 2-1 (source code 7) presents the ROPCs identified by Kupfer and others (1997).

2.2 COPC Adjustments as a Result of Revisions to the Toxic Air Pollutants

In 2009, Ecology issued a revision to the list of toxic air pollutants (WAC 173-460). The revision both added and removed TAPs that were previously used as input to the RDQO (Wiemers and others 1998).

The revised toxic air pollutant list identifies 395 TAPs. These TAPs were compared with the three primary inputs used to determine appropriate WTP COPCs:

- Constituents previously evaluated as input to the RDQO (including those constituents eliminated or retained as COPCs) (Section 2.1.1)
- Low-toxicity constituents screened out and added back at the request of Ecology (Section 2.1.2)
- Constituents identified by CHG industrial hygiene chemical vapor program (Section 2.1.4). Note, if the constituents appear on the CHG vapor study list, they were not evaluated in the TAPs revision evaluation.

The results of that evaluation are discussed in Section 2.2.1. The evaluation included an assessment of those TAPs formerly considered Class A or B TAPs, but removed from regulation in the WAC revision, and those constituents not previously identified as Class A or B TAPs, but added as a result of the WAC revision.

Those COPCs removed by the WAC 173-460 update (old TAPs) were compared with the latest updates to TWINS (PNNL 2010) tank waste analytical data and the Best Basis Inventory (PNNL 2010). Those COPCs with more than ten instances of detection in tank waste (TWINS), or listed with a quantity value in the BBI, were retained as feed COPCs. However, if the COPC was identified as a feed COPC in the RDQO (Section 2.1.1), or identified as low-toxicity compounds added at the request of Ecology and EPA (Section 2.1.2), solely because they were formerly regulated as a Class A or B TAP and they did not meet the TWINS or BBI retention criteria, then the constituent was eliminated as a potential COPC. Section 2.2.2 discusses the evaluation of the old TAPs.

The evaluation resulted in the removal[3] of 79 feed constituents previously identified in the RDQO starting list of 173 organic and inorganic constituents, or previously identified as one of the 111 compounds added back as low-toxicity constituents (37 from the 125 organic RDQO COPCs [Table 2-2, adjustment codes 3, 4, and 7], 42 from the low-toxicity list [Table 2-2, adjustment codes 5, 6, and 8]). Three additional compounds were removed by the evaluation (2 from the RDQO starting list and 1 from the low-toxicity list); however, they were detected in the CHG vapor study and therefore retained as feed COPCs (Table 2-2[4], adjustment codes 9 and 10). Section 2.1.4.1 discusses the CHG vapor study organic compounds and Section 2.3.1 discusses constituents for which there are no appropriate analytical methods for the tank waste matrix.

Appendix C provides details of the TAPs update and the subsequent changes.

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[3] Eleven (11) of the removed RDQO and low-toxicity COPCs appearing on the EPA or site-specific PIC lists were added back as stack emissions COPCs (Sections 2.4.4 and 2.4.5).

[4] Trimethylamine (CAS No. 75-50-3) one was eventually dropped from consideration because of a lack of a valid analytical method for constituent in the waste matrix (Table 2-2, adjustment code 12 with footnote d).

2.2.1 Evaluation of the New List of Toxic Air Pollutants

The 395 compounds identified as TAPs by the WAC 173-460 revision were evaluated to determine if changes were made to the WTP COPC list. The results of the evaluation of the TAPs list are:

- 1 organic constituent previously included as a feed COPC by the RDQO process, but removed by UHC/UTS, DST Part A review, was reinstated because it appears on the revised TAPs list
- 1 organic constituent previously included as a low-toxicity compound, but removed by UHC/UTS, DST Part A review, was reinstated because it appears on the revised TAPs list
- 6 inorganic compounds were identified to be measured in stack emissions [criteria pollutants (2 compounds), or added by agreement with Ecology (4 compounds)]. The 6 stack emissions compounds are discussed in Section 2.4.2.
- 71 compounds identified as potential stack emissions compounds; 70 are EPA PICs (note that 3 of the compounds are generic categories and are not individally measured in stack emissions) and 1 is a site-specific PIC; see Sections 2.4.4 and 2.4.5 for more discussion.

Appendix C, Table C-1 provides details of the new TAPs list evaluation.

2.2.2 Evaluation Old List of Toxic Air Pollutants

The update to the TAPs list made significant changes to the Class A and B TAPs constituents that were input to the RDQO. The Class A and B TAPs lists, before revision, were comprised of 669 compounds. The revised TAPs list retained only 209 of the former Class A and B TAPs (Section 2.2.1). The 460 constituents removed by the revision were evaluated to determine if they were included as COPCs solely because they were previously present in the toxic air pollutant regulations as Class A or B TAPs or if they appear as other RDQO inputs (Appendix C). The result of the analysis of the 460 former TAPs is as follows:

- 50 TAPs removed from the TAPs list by the TAPs regulation update were input to the RDQO (Table A-1) because they also were identified as a UHC, DST Part A DST, UTS, DST waste stream profile sheet (WSPS) or flammable gas constituent, either as part of the initial RDQO process. Eight of the 50 constituents were determined to be no longer regulated as either TAPs or UHCs. These were further evaluated as described in the discussion of 418 TAPS removed from regulation below. The remaining 42 TAPs were dispositioned as follows (see Section C.2):
    - 24 organics were previously identified either as RDQO starting list of 125 organics or low-toxicity list of compounds (Sections 2.1.1.1 and2.1.2,) and were therefore retained as COPCs
    - 1 organic compound eliminated in the RDQO process was reevaluted as part of the UHC/UTS, DST Part A update evaluation (Section 2.1.3); it was found in TWINs or BBI in excess of the retention criteria; this compound did not previously appear on either the RDQO or low-toxicity lists, but because of it's discovery in TWINS/BBI, it was added as a COPC (2.1.3)
    - 3 inorganics were identified as part of the RDQO process (Section 2.1.1.2) and were therefore retained as COPCs

- 14 compounds were removed from further consideration as feed COPCs because they were not in the final RDQO list, low-toxicity constituent list, a CHG vapor COPC, or in TWINS/BBI; note, 3 of the removed constituents are identified later as stack emisions compounds (Sections 2.4.4 and 2.4.5).

- 418 TAPs removed by the TAPs regulation update (including 8 RDQO constituents which were no longer considered UHCs since the update of 40 CFR 268) were evaluated because they were formerly identified as a Class A or Class B TAPs. The 418 compounds were dispositioned as follows:
  - 42 of the TAPs removed by update were on the RDQO list of 125 compounds and identified as WTP feed constituents. The following adjustments were made:
    - 3 were found in TWINS or BBI and retained
    - 2 were CHG vapor study compounds (Section 2.1.4); note, 1 was later removed (Section 2.3.1)
    - 37 were removed because they are no longer regulated and were not in TWINS/BBI[5].
  - 43 of the TAPs removed by update were on the low-toxicity list of 111 compounds and identified as WTP feed constituents. The following adjustments were made:
    - 1 was a CHG vapor study compound (Section 2.1.4)
    - 42 were removed because they are no longer regulated and were not in TWINS/BBI[6].
  - 95 are inorganic compounds. They were dispositioned as follows:
    - 5 were previously identified in the RDQO and not further evaluated
    - 90 inorganic compounds are addressed as individual ions in the waste feed and not further evaluated.
  - 238 remaining TAPs removed by the WAC revision were not identified as COPCs by the RDQO process. They were dispositioned as follows:
    - 1 was a CHG vapor study compound (Section 2.1.4) and was retained as a feed COPC
    - 237 were eliminated[7].

2.3 Regulatory Data Quality Objectives Optimization Study COPC List Adjustments

The RDQO (Wiemers and others 1998) required that the COPC analyte selection and analytical methods be optimized. The optimization effort is documented in the *Regulatory Data Quality Objectives Optimization Report* (BNI 2004). The adjustments removed 15 compounds (5 organics and 10 inorganics) and added nine (5 organics and 4 inorganics). Details of these optimization process adjustments (Section 2, Step 6) are provided in Appendix D.

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[5] Eight (8) of the removed RDQO COPCs are later added as stack emissions compounds (Sections 2.4.4 and 2.4.5)

[6] Seven (7) of the removed low-toxicity COPCs are later added as stack emissions compounds (Sections 2.4.4 and 2.4.5)

7 Thirteen (13) of the eliminated compounds are on EPA's list of PICs will be managed as such (Section 2.4.4)

2.3.1 Optimization Study Adjustments to the Regulatory Data Quality Objectives

The RDQO Optimization Report (BNI 2004) evaluated the list of RDQO COPCs in the context of optimizing feed analysis. As a result, tank waste characterization needs were adjusted to better suit the needs of the RDQO. Adjustments were made to the organic and inorganic COPC lists. Additional details of these adjustments are provided in Appendix D.

2.3.1.1 Adjustments to the Organic COPC List

The optimization study adjustments to the RDQO organic COPC feed list include the removal of eight organics from the WTP feed COPC list (including removal of total PCBs, CAS 1336-36-3) and the addition of seven aroclor mixtures (refer to Appendix D). Note, three of the organics were previously removed in the TAPs evaluation (Section 2.2.2); Appendix C, Table C-4 provides additional detail. Also, two of the aroclors, aroclor-1254 (CAS No. 11097-69-1) and aroclor-1242 (CAS No. 53469-21-9), have already been identified as feed COPCs by the CHG vapor study (Section 2.1.4.1).

Total PCBs, CAS 1336-36-3, which also is listed as an EPA PIC will be retained in the WTP feed COPCs list and aroclors will be removed as a result of later evaluation and agreements with Ecology (Section 2.5.1.2). Methyl isocyanate, CAS No. 624-83-9, appears as an EPA PIC and will be added back as discussed in Section 2.4.4. Also, methylhydrazine, CAS No. 60-34-4 is listed as a vapor compound in the CHG vapor study (Section 2.1.4). However, the optimization study removed it because there are no suitable analytical techinques for identifying the compound in Hanford tank waste matrices. Therefore, it was not retained as a feed COPC. Table 2-2 documents these changes.

2.3.1.2 Adjustments to the Inorganic COPC List

Optimization study adjustments to the RDQO inorganic feed COPC list include (Section 2, Step 6) the removal of six inorganics from the RDQO starting list of 48 and substitution of four inorganic constituents for similar compounds (BNI 2004). The changes totaled 10 eliminations and four additions. One inorganic ion, hexavalent chromium, CAS No. 18540-29-9, removed in the RDQO optimization study, appears on the EPA PIC list (Section 2.4.4). It is later removed; see Section 2.5.2 for discussion. Another inorganic addition, pH was later removed (Section 2.5.2). Table 2-1 provides the list of retained COPCs (source code 8) and Table 2-2 (adjustment codes 13 and 14) documents these changes.

2.4 Constituents in WTP Stack Emissions

In addition to WTP waste feed constituents, other COPCs are included because of their potential to form in the WTP processes and exit as stack emissions. These COPCs include compounds from the CHG vapor study, the revision to the WAC 173-460 list of toxic air pollutants, EPA-identified PICs, the EPA list of criteria pollutants, and site-specific WTP identified organic PICs. These stack emissions COPCs are discussed in the following subsections.

2.4.1 Stack Emissions COPCs Identified in CHG Vapor Study

Three compounds identified in the CHG vapor study are more appropriately measured in WTP stack emissions (as opposed to in the waste feed). The compounds are carbon monoxide, carbon dioxide and nitrogen dioxide. The compounds are identified in Table 2-1 as CHG added stack emissions compounds (source code 9).

The two carbon compounds identified in the vapor headspace are gases, carbon monoxide and carbon dioxide. Carbon monoxide would not be present in a vapor form in the tank wastes; it is classified by EPA as a criteria pollutant and will be measured in stack emissions only. Carbon dioxide will not be measured but will be dealt with qualitatively as agreed with Ecology (CCN 170036).

Nitrogen dioxide is a gas that would not be present in the vapor form in tank liquids, it is also classified by EPA as a criteria pollutant. It is more appropriately measured in stack emissions. Therefore, it was moved from a feed constituent to a constituent to be measured in stack emissions only.

2.4.2 Stack Emissions COPCs from TAPs Revision

The evaluation of the changes to the WAC 173-460 list of toxic air pollutants identified additional constituents that did not meet the criteria for waste feed COPCs (Section 2.2). Those compounds removed as WTP feed COPCs were further evaluated to determine if they should be measured in stack emissions (Section 2, Step 7). From the updated list of TAPs, the evaluation resulted in the following:

- 4 constituents that are also criteria pollutants were designated as stack emissions COPCs. Section 2.4.3 describes how these COPCs are managed[8] (Table 2-1, footnote e and source code 10).
- 4 inorganic constituents were retained as COPCs based on a previous agreement to sample for them as stack emissions COPCs (CCN 097844)[9] (Table 2-1, source code 11).
- 29 dioxins, furans, and coplanar polychlorinated biphenyl (PCB) compounds were added as stack emission COPCs (Table 2-1, source code 13); EPA has identified the dioxins and furans as PICs and the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP) (EPA 1998) identifies the coplanar PCBs as PICs (Appendix C, Table C-1, disposition 11).
- 38 constituents that did not meet the criteria for listing as feed COPCs appear on the EPA PIC list (Table 2-1, source code 13); these TAPs will be added as stack emissions COPCs (Appendix C, Table C-1, disposition 13) (Section 2.4.4).
- 1 constituent that did not meet the criteria for listing as feed COPCs appears on the site-specific PIC list (Table 2-1, source code 14); this TAP will be added as stack emissions COPCs (Appendix C, Table C-1, disposition 14).

Appendix C and Table C-1 provide additional details of the evaluation of new TAPs.

For the 418 former TAPs removed by the update, the stack emissions evaluation was similar to the new TAPs list as described above. The evaluation produced the following:

[8] Nitrogen dioxide and carbon monoxide (Table 2-1, source code 9) were previously identified in the CHG vapor study (Section 2.4.1). The remaining two compounds, ozone and sulfur dioxide were added to the list as stack emissions COPCs.

[9] The agreement documented in CCN 097844 actually added three halogens, hydrogen chloride, hydrogen fluoride, and chlorine; the halogen fluorine that is included in the waste envelope description for WTP waste feed was retained as well for completeness.

- 26 compounds that did not meet the criteria for listing as feed COPCs appear on the EPA PIC list (Table 2-1, source code 13). These include the following stack emissions COPCs (Section 2.4.4 and Appendix E):
  - 10 compounds previously identified as feed COPCs and removed in the TAPs revision evaluation appear on the EPA PIC list (Section 2.4.4) and were added as stack emissions COPCs:
    - 5 in the RDQO starting list of 125 constituents (Section 2.1.1.1) (Table 2-2, adjustment code 3)
    - 5 in the low-toxicity list (Section 2.1.2) (Table 2-2, adjustment code 5)
  - 16 constituents that did not meet the criteria for listing as feed COPCs appear on the EPA PIC list and were added as stack emissions COPCs (Table 2-2, adjustment code 15).
- 5 compounds previously identified as feed COPCs and removed in the TAPs revision evaluation appear on the site-specific PIC list (Section 2.4.5) and were added as stack emissions COPCs (Table 2-1, source code 14):
  - 3 in the RDQO starting list of 125 constituents (Section 2.1.1.1) (Table 2-2, adjustment code 4)
  - 2 in the low-toxicity list (Section 2.1.2) (Table 2-2, adjustment code 6)
- 1 constituent that did not meet the criteria for feed COPCs appears on the site-specific PIC list (Table 2-1, source code 14) and will be added as stack emissions COPCs (Table 2-2, adjustment code 16).

2.4.3 Criteria Pollutants

National ambient air quality standards (40 CFR 60) have been established for six criteria pollutants: sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. Two of these criteria pollutants, carbon monoxide and nitrogen dioxide, were identified by the CHG vapor study (Sections 2.1.4 and 2.4.1). Two compounds, ozone and sulfur dioxide, were identified by the revision to the WAC 173-460 list of toxic air pollutants (Section 2.4.2). Particulate matter is an addition to the stack emissions COPCs (Section 2, Step 8). Lead was previously identified by the RDQO process as an inorganic WTP feed COPC.

Sulfur dioxide and particulate matter will be measured in stack emissions along with carbon monoxide and nitrogen dioxide (Section 2.4.1). Ozone will be evaluated qualitatively as agreed with Ecology and EPA (CCN 170036).

2.4.4 Environmental Protection Agency Products of Incomplete Combustion

The PICs identified by the EPA were added to the WTP COPC list (Section 2, Step 9). As noted in Section 2.4.2, a number of constituents will be measured as stack emissions because EPA has identified them as PICs and there is no data to suggest their presence in the waste feed.

For combustion facilities, the EPA list of recommended and potential PICs is contained in Table A.1 of the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP) (EPA 1998). These chemicals include PICs from a variety of combustion units, but not specifically from vitrification units. The EPA identified 254 PICs (234 organic and 20 inorganic COPCs), including the 12 coplanar PCBs identified in the latest revision of the HHRAP, Table 2-5 (EPA 2005), as PICs. See Appendix E for additional discussion.

The organic and inorganic chemicals retained by the COPC identification processes described in the sections above (Section 2, Steps 1 to 8) were compared to the EPA PIC list. EPA identified PICs were added to the WTP COPC list if they were not:

- Previously identified for analysis in WTP waste feed (Sections 2.1, 2.2, and 2.3)
- Previously identified for measurement in stack emissions by the CHG vapor study (Section 2.4.1)
- Previously identified as criteria pollutants (Section 2.4.3)

Note, a number of EPA PICs were identified previously in the TAPs evaluation (Section 2.4.2).

A total of 128 compounds were initially identified as EPA PICs, 2 inorganic and 126 organics. Note, the inorganic hexavalent chromium, CAS No. 18540-29-9, and the organics total PCBs, CAS 1336-36-3 and methyl isocyanate; CAS No. 624-83-9 were removed as feed constituents by the RDQO Optimization Study (Section 2.3). These compounds appear on the EPA PIC list and were retained as stack emissions compounds. Later in the process Section 2, Step 12, a further adjustment was made to move total PCBs to a feed COPC and to remove hexavalent chromium as a stack emission compound; hexavalent chromium was replaced by total chromium as a WTP feed COPC (Section 2.5.3).

These compounds are further adjusted to 138 organics and 1 inorganics as described in Section 2.5.3 below. Table 2-1 (source code 13) lists the EPA PICs; Appendix E provides details of the PIC selection, with subsequent adjustments to the PIC list described in Appendix G.

2.4.5 Site-Specific Products of Incomplete Combustion

The list of site-specific PIC compounds were identified next (Section 2, Step 10). Between 1998 and 2005, a series of offgas emission tests were conducted on various configurations of laboratory and pilot-scale vitrification melters by Catholic University of America, Vitreous State Laboratory (VSL). Emissions data from these tests were used to identify additional COPCs to be assessed in dangerous waste and air permitting activities (Appendix F). The testing identified 144 compounds; 111 of those were identified previously by the WTP COPC identification process as WTP feed constituents or stack emission measurement compounds (criteria pollutants or EPA PICs), leaving 33 site-specific organic

PICs[10] that were added to the COPC list (Table 2-1, source code 14). Appendix F summarizes the tests conducted and identifies detected constituents.

2.5 Adjustments to the Constituents of Potential Concern

The consolidated list of COPCs resulting from Section 2, Steps 1 through 11, totals 434 individual COPCs/ROPCs: 333 organics, 55 inorganics (217 feed COPCs and 171 stack emission COPCs), and 46 feed ROPCs. The consolidated list was reviewed with the EPA and Ecology (Section 2, Step 11) as part of the risk assessment work plan discussions described in the following sections. The review used a systematic approach by evaluating constituents in accordance with the precedent set for selecting constituents of concern. This meant that the 388 individual COPCs and 46 ROPCs were evaluated in the context of the RDOQ, revised list of toxic air pollutants, RDQO optimization study, low-toxicity constituents, PIC production, and constituent toxicity and radioactivity. Decision makers examined the outcome of Steps 1 through 10 for validity and made adjustments as summarized below. These adjustments are discussed in the subsections that follow. Table 2-2 tabulates the changes and identifies the reason for the adjustment.

2.5.1 Adjustments to the Waste Feed Organic COPCs List

The adjustments to the starting list of 125 RDQO feed organic COPCs are described in the following subsections.

2.5.1.1 Adjustments to the List of Organic Polycyclic Aromatic Hydrocarbons and Pesticides

Adjustments to the WTP feed COPC list include removal of compounds not detected in tank waste, reversal of some adjustments made by the RDQO optimization study, and replacement of some organic compounds. These adjustments are discussed in this section.

In September 2004, the WTP COPC list was reconsidered (CCN 097844) with regard to 31 organic compounds that had not been detected in the Hanford tank waste. The 31 compounds consist of 22 particle-bound constituents and 9 vapor-phase constituents. The 31 compounds will be managed as follows:

- 1 particle-bound low toxicity compound originally proposed to be measured as PICs were identified in the CHG vapor study and will be retained as a feed COPC (Table 2-2, adjustment code 17)
- 9 particle-bound compounds (3 RDQO and 6 low-toxicity COPCs, Table 2-2 adjustment codes 18 and 19) that have not been detected in Hanford tank waste appear on the EPA PIC list, and will be managed as PICs
- 12 particle-bound constituents (5 RDQO and 7 low-toxicity COPCs, Table 2-2 adjustment codes 20 and 21) (one of which had already been eliminated by the TAPs revision evaluation) are herbicides or pesticides without detection or a history of use/addition to tank waste and will be eliminated as COPCs
- 1 vapor-phase RDQO COPC previously proposed to be managed as a PIC was found in TWINS or BBI and retained as a feed COPC (Table 2-2, adjustment code 22)

[10] Note, seven (7) of the site-specific PICs were previously identified as stack emissions compounds in the TAPs revision evaluation (Section 2.4.2).

- 5 vapor-phase compounds (4 RDQO and 1 low-toxicity COPCs) appear on the EPA PIC list, and will be managed as PICs (Table 2-2, adjustment code 23)
- 3 vapor-phase compounds (1 RDQO and 2 low-toxicity COPCs) (one of which had already been eliminated by the TAPs revision evaluation) are herbicides or pesticides without detection or a history of use/addition to tank waste and will be eliminated as COPCs (Table 2-2, adjustment code 24)

Appendix G provides details of the adjustments. In all, 14 COPCs were reassigned from feed to PICs, 2 were retained as feed instead of being reassigned to PICs, and 15 COPCs were eliminated (2 were previously eliminated during the TAPs evaluation).

2.5.1.2 Additional Adjustments to the WTP Organic COPC Feed List

Additional adjustments were made to the RDQO starting list that further reduced the number of feed COPCs:

- Seven aroclors that were added by the RDQO optimization study and the CHG vapor study in place of total PCBs were removed as COPCs and replaced by total PCBs (Table 2-2, source code 26). Total PCBs was moved from EPA PIC to a feed COPC (Table 2-2, adjustment code 25)
- Three individual isomers of xylene were removed; total xylenes will be used instead; note total xylenes has already been assigned to the feed COPC list from the evaluation of changes to the UHC/UTS, DST Part A lists (Section 2.1.3) (Table 2-2, adjustment codes 27 and 28).

2.5.2 Adjustments to the Inorganic Waste Feed COPC List

The RDQO optimization study substituted the measurement of pH for hydroxide. The pH measurement was removed as a COPC (Table 2-2, adjustment code 29) to be evaluated in the air permits and risk assessment (Appendix G). The measurement of pH will continue in the waste feed.

2.5.3 Adjustments to the EPA List of Products of Incomplete Combustion

The following additional adjustments were made to the constituents that appeared on the list of EPA PICs:

- 14 compounds removed from the WTP feed COPC list (Section 2.5.1.1) were added to the EPA PIC list (Table 2-2, adjustment codes 18, 19 and 23), and two constituents that were proposed to be moved to the EPA PIC list that were found in TWINS/BBI or the CHG vapor study and retained as feed COPCs
- Total PCBs was moved from EPA PIC to a feed COPC (Table 2-2, adjustment code 25)
- Total xylenes was removed from the PIC list since it is considered a feed COPC (Section 2.5.1.2, Table 2-2, adjustment code 28)
- Three individual isomers of xylene were removed from the PIC list if favor of total xylenes, characterized as a feed constituent (Appendix G, Table 2-2, adjustment code 27)
- One polycyclic aromatic hydrocarbon (dibenzo[a,h]fluoranthene, no CAS number), previously identified by EPA as a PIC, cannot structurally exist; it was removed from consideration as a COPC (Table 2-2, adjustment code 30)

- Hexavalent chromium appears on the EPA PIC list; total chromium will be evaluated in WTP feed and assessed as if it is hexavalent chromium, therefore the EPA PIC was removed (Appendix G, Table 2-2, adjustment code 31).

2.5.4 COPCs that are Evaluated as both Radionuclides and Non-Radionuclides

Eleven inorganic COPCs identified in the RDQO are also identified as ROPCs. These 11 COPCs will be evaluated as radioactive and non-radioactive constituents. Table 2-1 identifies these compounds. There is no non-radioactive form of uranium. Uranium-238 was identified by the RDQO for it's non-radioactive effects and by the same CAS number (CAS 7440-61-1) in Kupfer and others (1997). An "R" was added to the CAS number of uranium-238 (CAS 7440-61-1R) to distinguish the radioactive effects from the non-radioactive effects for risk assessment. Table 2-1 notes identify the CAS number change.

One additional compound, strontium, was added to the COPC list in accordance with the agreement with Ecology and EPA (CCN: 017190C). Stable strontium is identified with a note in the tables and by its unique CAS number (Table 2-1, source code 16).

2.5.5 COPCs that are Evaluated Qualitatively

Carbon dioxide was identified in the CHG vapor study as a stack emission compound (Section 2.4.1). Ozone was identified by EPA as a criteria pollutant (Section 2.4.3). As agreed during discussions with Ecology, these two constituents will be evaluated qualitatively (Table 2-2, adjustment code 32). See Appendix G for additional discussion.

2.6 Categorization of Constituents of Potential Concern

In conclusion, the WTP COPC list consists of 409 compounds; 363 COPCs and 46 ROPCs. The following categorization summarizes the number and type of COPCs and ROPCs, as described in Table 2-1 and depicted by Figure 2-1:

- 309 organic COPCs, including:
  - 138 feed compounds
  - 171 stack emissions compounds
- 54 inorganic COPCs, including:
  - 43 feed compounds (11 with radioactive forms)
  - 11 stack emissions compounds
- 46 ROPCs (all feed constituents)

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
100-41-4	Ethyl benzene	1		
100-42-5	Styrene	1		
10061-01-5	cis-1,3-Dichloropropene	1		
10061-02-6	trans-1,3-Dichloropropene	1		
106-46-7	1,4-Dichlorobenzene	1		
106-93-4	Ethylene dibromide	1		
106-99-0	1,3-Butadiene	1		
107-02-8	Acrolein	1		
107-05-1	3-Chloropropene	1		
107-06-2	1,2-Dichloroethane	1		
107-12-0	Propionitrile	1		
107-13-1	Acrylonitrile	1		
108-10-1	4-Methyl-2-pentanone	1		
108-88-3	Toluene	1		
108-90-7	Chlorobenzene	1		
108-94-1	Cyclohexanone	1		
108-95-2	Phenol	1		
110-54-3	n-Hexane	1		
110-82-7	Cyclohexane	1		
110-86-1	Pyridine	1		
120-82-1	1,2,4-Trichlorobenzene	1		
122-39-4	N,N-Diphenylamine	1		
123-91-1	1,4-Dioxan	1		
126-73-8	Tributyl phosphate	1		
126-98-7	2-Methyl-2-propenenitrile	1		
127-18-4	1,1,2,2-Tetrachloroethene	1		
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	1		
141-78-6	Acetic acid ethyl ester	1		
50-32-8	Benzo(a)pyrene	1		
53-70-3	Dibenz[a,h]anthracene	1		
541-73-1	1,3-Dichlorobenzene	1		
56-23-5	Carbon tetrachloride	1		
591-78-6	2-Hexanone	1		
62-75-9	N-Nitroso-N,N-dimethylamine	1		
67-56-1	Methyl alcohol	1		
67-63-0	2-Propyl alcohol	1		
67-64-1	2-Propanone (Acetone)	1		
67-66-3	Chloroform	1		
71-36-3	n-Butyl alcohol	1		
71-43-2	Benzene	1		

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
71-55-6	1,1,1-Trichloroethane	1		
74-83-9	Bromomethane	1		
74-87-3	Chloromethane	1		
75-00-3	Chloroethane	1		
75-01-4	1-Chloroethene	1		
75-05-8	Acetonitrile	1		
75-09-2	Dichloromethane (Methylene Chloride)	1		
75-15-0	Carbon disulfide	1		
75-21-8	Ethylene oxide (Oxirane)	1		
75-34-3	1,1-Dichloroethane	1		
75-35-4	1,1-Dichloroethene	1		
75-45-6	Chlorodifluoromethane	1		
75-69-4	Trichlorofluoromethane	1		
75-71-8	Dichlorodifluoromethane	1		
76-13-1	1,2,2-Trichlorotrifluoroethane	1		
78-87-5	1,2-Dichloropropane	1		
78-93-3	2-Butanone	1		
79-00-5	1,1,2-Trichloroethane	1		
79-01-6	1,1,2-Trichloroethylene	1		
79-10-7	2-Propenoic acid	1		
79-34-5	1,1,2,2-Tetrachloroethane	1		
87-68-3	Hexachlorobutadiene	1		
87-86-5	Pentachlorophenol	1		
95-50-1	1,2-Dichlorobenzene	1		
98-86-2	Acetophenone	1		
98-95-3	Nitrobenzene	1		
14265-44-2	Phosphate	2		
14797-65-0	Nitrite	2		
14808-79-8	Sulfate	2		
16887-00-6	Chloride	2		
16984-48-8	Fluoride	2		
24959-67-9	Bromide	2		
57-12-5	Cyanide	2		
7429-90-5	Aluminum	2		
7439-89-6	Iron	2		
7439-92-1	Lead	2		
7439-93-2	Lithium	2		
7439-95-4	Magnesium	2		
7439-96-5	Manganese	2		
7439-97-6	Mercury	2		
7439-98-7	Molybdenum	2		

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
7440-02-0	Nickel	2		y
7440-16-6	Rhodium	2		
7440-22-4	Silver	2		
7440-23-5	Sodium	2		
7440-25-7	Tantalum	2		
7440-28-0	Thallium	2		
7440-31-5	Tin	2		y
7440-33-7	Tungsten	2		
7440-36-0	Antimony	2		y
7440-38-2	Arsenic	2		
7440-39-3	Barium	2		y
7440-41-7	Beryllium	2		
7440-43-9	Cadmium	2		y
7440-48-4	Cobalt	2		y
7440-50-8	Copper	2		
7440-61-1	Uranium	2		y
7440-62-2	Vanadium	2		
7440-65-5	Yttrium	2		y
7440-66-6	Zinc	2		
7440-67-7	Zirconium	2		y
7664-41-7	Ammonia/Ammonium	2		
7723-14-0	Phosphorus	2		
7782-49-2	Selenium	2		y
100-21-0	Phthalic acid	3		
101-55-3	4-Bromophenylphenyl ether	3		
106-88-7	1,2-Epoxybutane	3		
108-05-4	Acetic acid vinyl ester	3		
108-39-4	m-Cresol	3		
111-76-2	2-Butoxyethanol	3		
117-81-7	Bis(2-ethylhexyl) phthalate	3		
117-84-0	Di-n-octylphthalate	3		
120-12-7	Anthracene	3		
120-83-2	2,4-Dichlorophenol	3		
129-00-0	Pyrene	3		
156-60-5	1,2-trans-Dichloroethene	3		
1634-04-4	Methyl tert-butyl ether	3		
189-55-9	Dibenzo[a,i]pyrene	3		
189-64-0	Dibenzo[a,h]pyrene	3		
191-24-2	Benzo(g,h,i)perylene	3		
191-30-0	Dibenzo(a,l)pyrene	3		
192-65-4	Dibenzo[a,e]pyrene	3		

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
193-39-5	Indeno(1,2,3-cd)pyrene	3		
206-44-0	Fluoranthene	3		
208-96-8	Acenaphthylene	3		
224-42-0	Dibenz[a,j]acridine	3		
226-36-8	Dibenz[a,h]acridine	3		
27154-33-2	Trichlorofluoroethane	3		
3697-24-3	5-Methylchrysene	3		
50-00-0	Formaldehyde	3		
56-49-5	3-Methylcholanthrene	3		
58-90-2	2,3,4,6-Tetrachlorophenol	3		
59-50-7	4-Chloro-3-methylphenol	3		
59-89-2	N-Nitrosomorpholine	3		
602-87-9	5-Nitroacenaphthene	3		
60-29-7	Ethyl ether	3		
60-35-5	Acetamide	3		
621-64-7	N-Nitroso-di-n-propylamine	3		
630-20-6	1,1,1,2-Tetrachloroethane	3		
67-72-1	Hexachloroethane	3		
75-07-0	Acetaldehyde	3		
75-27-4	Bromodichloromethane	3		
78-83-1	2-Methylpropyl alcohol	3		
83-32-9	Acenaphthene	3		
84-66-2	Diethyl phthalate	3		
84-74-2	Di-n-butylphthalate	3		
85-01-8	Phenanthrene	3		
85-68-7	Butylbenzylphthalate	3		
86-73-7	Fluorene	3		
88-06-2	2,4,6-Trichlorophenol	3		
88-75-5	2-Nitrophenol	3		
91-20-3	Naphthalene	3		
91-58-7	2-Chloronaphthalene	3		
95-48-7	o-Cresol	3		
95-57-8	2-Chlorophenol	3		
95-95-4	2,4,5-Trichlorophenol	3		
98-82-8	Cumene	3		
100-02-7	p-Nitrophenol	4		
110-80-5	2-Ethoxyethanol	4		
121-14-2	2,4-Dinitrotoluene	4		
1330-20-7	Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations)	4		
79-46-9	2-Nitropropane	4		

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
100-40-3	4-Ethenylcyclohexene	5		
104-76-7	2-Ethyl-1-hexanol	5		
10595-95-6	n-Nitrosomethylethylamine	5		
109-74-0	n-Butanenitrile	5		
110-59-8	Pentanenitrile	5		
123-72-8	Butanal	5		
134-32-7	alpha-Naphthylamine	5		
589-38-8	3-Hexanone	5		
628-73-9	Hexanenitrile	5		
72-55-9	4,4-DDE	5		
75-02-5	Fluoroethene (vinyl fluoride)	5		
75-50-3	Trimethylamine	5		
92-52-4	1,1`-Biphenyl	5		
593-74-8	Dimethyl Mercury	6		
10028-17-8	Tritium	7		
10045-97-3	Cesium-137	7		
10098-91-6	Yttrium-90	7		
10098-97-2	Strontium-90	7		
10198-40-0	Cobalt-60	7		
13966-29-5	Uranium-234	7		
13967-48-1	Ruthenium-106	7		
13967-70-9	Cesium-134	7		
13968-55-3	Uranium-233	7		
13981-15-2	Curium-244	7		
13981-16-3	Plutonium-238	7		
13981-37-8	Nickel-63	7		
13982-10-0	Plutonium-242	7		
13982-63-3	Radium-226	7		
13982-70-2	Uranium-236	7		
13994-20-2	Neptunium-237	7		
14119-32-5	Plutonium-241	7		
14119-33-6	Plutonium-240	7		
14133-76-7	Technetium-99	7		
14158-29-3	Uranium-232	7		
14234-35-6	Antimony-125	7		
14331-85-2	Protactinium-231	7		
14336-70-0	Nickel-59	7		
14391-16-3	Europium-155	7		
14596-10-2	Americium-241	7		
14683-23-9	Europium-152	7		
14762-75-5	Carbon-14	7		

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
14952-40-0	Actinium-227	7		
14993-75-0	Americium-243	7		
15046-84-1	Iodine-129	7		
15117-48-3	Plutonium-239	7		
15117-96-1	Uranium-235	7		
15262-20-1	Radium-228	7		
15510-73-3	Curium-242	7		
15585-10-1	Europium-154	7		
15594-54-4	Thorium-229	7		
15715-94-3	Samarium-151	7		
15751-77-6	Zirconium-93	7		
15757-87-6	Curium-243	7		
15758-45-9	Selenium-79	7		
15832-50-5	Tin-126	7		
378253-40-8	Barium-137m	7		
378253-44-2	Cadmium-113m	7		
378782-82-2	Niobium-93m	7		
7440-29-1	Thorium-232	7		
7440-61-1R	Uranium-238 [d]	7		
14797-55-8	Nitrate	8		
7440-47-3	Chromium	8		
7704-34-9	Total Sulfur (thermodynamically stable)	8		
10102-44-0	Nitrogen dioxide [c]	9	x	
124-38-9	Carbon dioxide [f]	9	x	
630-08-0	Carbon monoxide [c]	9	x	
10028-15-6	Ozone [f]	10	x	
7446-09-5	Sulfur dioxide	10	x	
7647-01-0	Hydrogen chloride	11	x	
7664-39-3	Hydrogen Fluoride	11	x	
7782-41-4	Fluorine gas F2	11	x	
7782-50-5	Chlorine	11	x	
no CAS #2	Particlate matter	12	x	
100-25-4	1,4-Dinitrobenzene	13	x	
100-44-7	Benzyl chloride	13	x	
100-52-7	Benzaldehyde	13	x	
101-77-9	4,4-Methylenedianiline	13	x	
103-33-3	Azobenzene	13	x	
105-67-9	2,4-Dimethylphenol	13	x	
106-44-5	p-Cresol (4-methyl phenol)	13	x	
106-47-8	p-Chloroaniline	13	x	
106-49-0	p-Toluidine	13	x	

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
106-51-4	Quinone	13	x	
106-89-8	Epichlorohydrin (1-chloro-2,3 epoxypropane)	13	x	
107-19-7	Propargyl alcohol	13	x	
107-21-1	Ethylene glycol (1,2-ethanediol)	13	x	
107-98-2	Propylene glycol monomethyl ether	13	x	
108-60-1	bis (2-Chloroisopropyl)ether	13	x	
108-67-8	1,3,5-Trimethylbenzene	13	x	
108-87-2	Methylcyclohexane	13	x	
109-77-3	Malononitrile	13	x	
109-86-4	2-Methoxyethanol	13	x	
109-99-9	Tetrahydrofuran	13	x	
111-15-9	Ethylene glycol monoethyl ether acetate	13	x	
111-44-4	bis(2-Chloroethyl)ether	13	x	
111-91-1	bis(2-Chloroethoxy)methane	13	x	
1120-71-4	1,3-Propane sultone	13	x	
118-74-1	Hexachlorobenzene	13	x	
119-90-4	3,3'-Dimethoxybenzidine	13	x	
122-66-7	1,2-Diphenylhydrazine	13	x	
123-33-1	Maleic hydrazide	13	x	
123-38-6	Propionaldehyde	13	x	
124-48-1	Chlorodibromomethane	13	x	
131-11-3	Dimethyl Phthalate	13	x	
131-89-5	2-Cycloyhexyl-4,6-dinitrophenol	13	x	
132-64-9	Dibenzofuran	13	x	
133-06-2	Captan	13	x	
145-73-3	Endothall	13	x	
1746-01-6	2,3,7,8-Tetrachlorodibenzo(p)dioxin (TCDD)	13	x	
192-97-2	Benzo(e)pyrene	13	x	
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	13	x	
205-82-3	Benzo[j]fluoranthene	13	x	
205-99-2	Benzo(b)fluoranthene	13	x	
207-08-9	Benzo(k)fluoranthene	13	x	
218-01-9	Chrysene	13	x	
22967-92-6	Methyl mercury	13	x	
23950-58-5	Pronamide	13	x	
31508-00-6	2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	13	x	
319-84-6	alpha-BHC	13	x	
319-85-7	beta-BHC	13	x	
32598-13-3	3,3',4,4'-Tetrachlorobiphenyl (PCB 77)	13	x	
32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	13	x	

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
3268-87-9	Octachlorodibenzo(p)dioxin	13	x	
32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	13	x	
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	13	x	
38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)	13	x	
39001-02-0	Octachlorodibenzofuran	13	x	
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	13	x	
39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	13	x	
40321-76-4	1,2,3,7,8-Pentachlorodibenzo(p)dioxin	13	x	
4170-30-3	Crotonaldehyde (Propylene aldehyde)	13	x	
41851-50-7	Chlorocyclopentadiene	13	x	
460-19-5	Cyanogen (oxalonitrile)	13	x	
506-68-3	Cyanogen bromide (bromocyanide)	13	x	
506-77-4	Cyanogen chloride	13	x	
510-15-6	Chlorobenzilate	13	x	
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran	13	x	
51-28-5	2,4-Dinitrophenol	13	x	
51-79-6	Ethyl carbamate (urethane)	13	x	
52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	13	x	
528-29-0	1,2-Dinitrobenzene (o-Dinitrobenzene)	13	x	
532-27-4	2-Chloroacetophenone	13	x	
534-52-1	4,6-Dinitro-o-cresol	13	x	
5385-75-1	Dibenzo(a,e)fluoranthene	13	x	
540-73-8	1,2-Dimethylhydrazine	13	x	
540-84-1	2,2,4-Trimethylpentane	13	x	
542-75-6	1,3-Dichloropropene	13	x	
542-88-1	bis(Chloromethyl)ether	13	x	
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran	13	x	
56-55-3	Benzo(a)anthracene	13	x	
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	13	x	
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran	13	x	
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran	13	x	
57-24-9	Strychnine	13	x	
57465-28-8	3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	13	x	
57653-85-7	1,2,3,6,7,8,-Hexachlorodibenzo(p)dioxin	13	x	
57-74-9	Chlordane	13	x	
584-84-9	2,4-Toluene diisocyanate	13	x	
58-89-9	gamma-BHC (Lindane)	13	x	
593-60-2	Bromoethene (Vinyl bromide)	13	x	
60-11-7	Dimethyl aminoazobenzene	13	x	
606-20-2	2,6-Dinitrotoluene	13	x	

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran	13	x	
608-93-5	Pentachlorobenzene	13	x	
61626-71-9	Dichloropentadiene	13	x	
624-83-9	Methyl isocyanate	13	x	
62-50-0	Ethyl methanesulfonate	13	x	
62-53-3	Aniline	13	x	
64-18-6	Formic acid (methanoic acid)	13	x	
65510-44-3	2',3,4,4',5-Pentachlorobiphenyl (PCB 123)	13	x	
65-85-0	Benzoic acid	13	x	
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran	13	x	
69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)	13	x	
70-30-4	Hexachlorophene	13	x	
70362-50-4	3,4,4',5-Tetrachlorobiphenyl (PCB 81)	13	x	
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	13	x	
72-43-5	Methoxychlor	13	x	
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran	13	x	
74472-37-0	2,3,4,4',5-Pentachlorobiphenyl (PCB 114)	13	x	
74-95-3	Methylene bromide	13	x	
74-97-5	Bromochloromethane	13	x	
75-25-2	Bromoform	13	x	
75-29-6	2-Chloropropane	13	x	
75-44-5	Phosgene (hydrogen phosphide)	13	x	
76-01-7	Pentachloroethane	13	x	
764-41-0	1,4-Dichloro-2-butene	13	x	
76-44-8	Heptachlor	13	x	
765-34-4	Glycidylaldehyde	13	x	
77-47-4	Hexachlorocyclopentadiene	13	x	
77-78-1	Dimethyl sulfate	13	x	
822-06-0	Hexamethylene-1,5-diisocyanate	13	x	
823-40-5	Toluene-2,6-diamine	13	x	
82-68-8	Pentachloronitrobenzene (PCNB)	13	x	
85-44-9	Phthalic anhydride (1,2-benzenedicarboxylic anhydride)	13	x	
88-74-4	o-Nitroaniline (2-nitroaniline)	13	x	
90-04-0	o-Anisidine	13	x	
91-22-5	Quinoline	13	x	
91-94-1	3,3'-Dichlorobenzidine	13	x	
924-16-3	N-Nitroso-di-n-Buetylamine	13	x	
94-59-7	Safrole (5-(2-Propenyl)-1,3-benzodioxole)	13	x	
94-75-7	2,4-D	13	x	
95-53-4	o-Toluidine	13	x	
95-94-3	1,2,4,5-Tetrachlorobenzene	13	x	

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
96-12-8	1,2-Dibromo-3-chloropropane	13	x	
96-18-4	1,2,3-Trichloropropane	13	x	
96-45-7	Ethylene thiourea	13	x	
97-63-2	Ethyl methacrylate	13	x	
98-01-1	Furfural	13	x	
98-07-7	Benzotrichloride	13	x	
98-83-9	Methyl styrene (mixed isomers)	13	x	
99-35-4	1,3,5-Trinitrobenzene	13	x	
99-65-0	1,3-Dinitrobenzene	13	x	
100-47-0	Benzonitrile	14	x	
100-51-6	Benzyl alcohol	14	x	
103-65-1	n-Propyl benzene (Isocumene)	14	x	
104-51-8	n-Butylbenzene	14	x	
106-43-4	4-Chlorotoluene (p-Tolyl chloride)	14	x	
108-86-1	Bromobenzene (Phenyl bromide)	14	x	
109-75-1	3-Butenenitrile	14	x	
110-00-9	Furan	14	x	
110-83-8	Cyclohexene	14	x	
111-65-9	n-Octane	14	x	
111-84-2	n-Nonane	14	x	
1120-21-4	Undecane	14	x	
112-30-1	1-Decanol	14	x	
112-31-2	Decanal	14	x	
112-40-3	Dodecane	14	x	
124-18-5	Decane	14	x	
135-98-8	sec-Butylbenzene	14	x	
156-59-2	cis-1,2-Dichloroethene	14	x	
2245-38-7	2,3,5-Trimethylnaphthalene	14	x	
4786-20-3	2-Butenenitrile	14	x	
540-59-0	1,2-Dichloroethene (total) (1,2-Dichloroethylene)	14	x	
581-42-0	2,6-Dimethylnaphthalene	14	x	
591-50-4	Benzene, iodo-	14	x	
74-88-4	Iodomethane	14	x	
80-62-6	Methyl methacrylate	14	x	
832-69-9	1-Methylphenanthrene	14	x	
87-61-6	1,2,3-Trichlorobenzene	14	x	
90-12-0	1-Methylnaphthalene	14	x	
91-57-6	2-Methylnaphthalene	14	x	
95-49-8	o-Chlorotoluene	14	x	
95-63-6	1,2,4-Trimethyl benzene	14	x	
98-06-6	tert-Butyl benzene	14	x	

Table 2-1 Constituents of Potential Concern for WTP Air and Dangerous Waste Permitting Activities

CAS #	Constituent	Source [a]	PIC [b]	Both Rad and Non-Rad Forms Evaluated [c]
99-87-6	p-Cymene	14	x	
1336-36-3	Polychlorinated biphenyls (209 congeners)	15		
7440-24-6	Strontium (total)	16		y

Notes:

Source [a]
1 RDQO Starting List - organics (Section 2.1.1.1).
2 RDQO Starting List - inorganics (Section 2.1.1.2).
3 Low-toxicity list added at request of Ecology (Section 2.1.2).
4 Other inputs (e.g., UHCs) resulting from modifications to the RDQO input list; found in TWINS/BBI and added (Section 2.1.3).
5 CHG vapor study organic compounds (Section 2.1.4.1).
6 CHG vapor study inorganic compounds (Section 2.1.4.2).
7 ROPCs (Section 2.1.5).
8 Inorganic compounds added by RDQO Optimization study (Section 2.3).
9 CHG vapor study added compounds moved to stack emissions COPCs (Section 2.4.1).
10 New TAPs list constituents also identified by EPA as criteria pollutants; retained as stack emissions COPCs (Section 2.4.2).
11 New TAPs list constituents retained as stack emissions COPCs based on previous agreement with Ecology (Section 2.4.2).
12 Identified by EPA as a criteria pollutant (40 CFR 60) (Section 2.4.3).
13 EPA PIC (Section 2.4.4).
14 Site-specific PICs (Section 2.4.5).
15 Total PCBs; move from EPA PIC to feed by agreement with Ecology/EPA (CCN 170036) (Section 2.5.1.2).
16 Stable strontium added (Section 2.5.4)

[b] PIC - Product of incomplete combustion; the Source column lists the process that identified the PIC.

[c] The column identifies compounds that are potentially in the tank waste as both radioactive and non-radioactive components. Where data is available, both forms are evaluated in the permitting processes.

[d] An "R" was added to the CAS # to differentiate the radioactive form of uranium-238; both radioactive and non-radioactive effects will be evaluated.

[e] Criteria pollutant identified by CHG vapor study.

[f] Evaluated qualitatively.

Table 2-2 Adjustments to WTP Chemicals of Potential Concern

CAS#	Constituent	Reason for Adjustment [a]
14265-45-3	Sulfite	1
18496-25-8	Sulfides	1
7440-06-4	Platinum	1
7440-46-2	Cesium	1
10024-97-2	Nitrous oxide	2
108-87-2	Methylcyclohexane	3
109-99-9	Tetrahydrofuran	3
123-38-6	n-Propionaldehyde	3
4170-30-3	2-Butenaldehyde	3
64-18-6	Formic acid	3
110-83-8	Cyclohexene	4
111-65-9	n-Octane	4
111-84-2	n-Nonane	4
132-64-9	Dibenzofuran	5
540-84-1	2,2,4-Trimethylpentane	5
74-97-5	Bromochloromethane	5
91-22-5	Quinoline	5
98-83-9	Methylstyrene	5
540-59-0	1,2-Dichloroethylene	6
95-49-8	o-Chlorotoluene	6
100-00-5	p-Nitrochlorobenzene	7
106-35-4	3-Heptanone	7
106-97-8	Butane	7
107-87-9	2-Pentanone	7
109-66-0	n-Pentane	7
110-12-3	5-Methyl-2-hexanone	7
110-43-0	2-Heptanone	7
123-19-3	4-Heptanone	7
123-86-4	Acetic acid n-butyl ester	7
1321-64-8	Pentachloronaphthalene	7
1335-87-1	Hexachloronaphthalene	7
1335-88-2	Tetrachloronaphthalene	7
142-82-5	n-Heptane	7
144-62-7	Oxalic acid	7
2234-13-1	Octachloronaphthalene	7
287-92-3	Cyclopentane	7
3825-26-1	Ammonium perfluorooctanoate [c]	7
563-80-4	3-Methyl-2-butanone	7
627-13-4	Nitric acid, propyl ester	7
64-17-5	Ethyl alcohol	7
64-19-7	Acetic acid	7
684-16-2	Hexafluoroacetone [c]	7

Table 2-2 Adjustments to WTP Chemicals of Potential Concern

CAS#	Constituent	Reason for Adjustment [a]
71-23-8	n-Propyl alcohol	7
75-43-4	Dichlorofluoromethane	7
75-65-0	2-Methyl-2-propanol	7
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane	7
78-92-2	1-Methylpropyl alcohol	7
88-89-1	Picric acid [c]	7
96-22-0	3-Pentanone	7
101-84-8	Diphenyl ether	8
107-18-6	2-Propen-1-ol	8
107-31-3	Formic acid, methyl ester	8
107-66-4	Dibutylphosphate	8
108-03-2	1-Nitropropane	8
108-20-3	Bis(isopropyl) ether	8
108-93-0	Cyclohexanol	8
110-62-3	n-Valeraldehyde	8
121-69-7	Dimethylaniline	8
123-51-3	3-Methyl-1-butanol	8
127-19-5	N,N-Dimethylacetamide	8
1321-65-9	Trichloronaphthalene	8
141-79-7	4-Methyl-3-penten-2-one	8
1582-09-8	Trifluralin	8
25551-13-7	Trimethyl benzene	8
26140-60-3	Terphenyls	8
603-34-9	Triphenyl amine	8
74-99-7	Methylacetylene	8
75-12-7	Formamide	8
75-52-5	Nitromethane	8
75-55-8	2-Methylaziridine	8
75-61-6	Difluorodibromomethane	8
75-63-8	Trifluorobromomethane	8
75-99-0	2,2-Dichloropropionic acid [b]	8
76-03-9	Trichloroacetic acid	8
76-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane	8
76-12-0	1,1,2,2-Tetrachloro-1,2-difluoroethane	8
76-15-3	Chloropentafluoroethane	8
79-09-4	Propanoic acid	8
79-20-9	Methyl acetate	8
88-72-2	Nitrotoluene	8
92-93-3	4-Nitrobiphenyl	8
95-13-6	Indene	8
96-69-5	Bis(3-tert-butyl-4-hydroxy-6-methyl-phenyl) sulfide	8
98-51-1	p-tert-Butyltoluene	8
92-52-4	1,1`-Biphenyl	9

Table 2-2 Adjustments to WTP Chemicals of Potential Concern

CAS#	Constituent	Reason for Adjustment [a]
75-50-3	Trimethylamine	10
624-83-9	Methyl isocyanate	11
121-44-8	Triethylamine	12
57-14-7	1,1-Dimethylhydrazine	12
60-34-4	Methylhydrazine [d]	12
7440-09-7	Potassium	13
7440-21-3	Silicon	13
7440-42-8	Boron	13
7440-69-9	Bismuth	13
7440-70-2	Calcium	13
7553-56-2	Iodine	13
14280-30-9	Hydroxide	14
63705-05-5	Total Sulfur	14
7697-37-2	Nitrate	14
106-49-0	p-Toluidine	15
106-51-4	p-Benzoquinone	15
107-19-7	Propargyl alcohol	15
119-90-4	3,3'-Dimethoxybenzidine	15
131-11-3	Dimethyl phthalate	15
460-19-5	Cyanogen	15
506-77-4	Cyanogen chloride	15
51-28-5	2,4-Dinitrophenol	15
528-29-0	Dinitrobenzene, all isomers	15
534-52-1	4,6-Dinitro-o-cresol	15
57-24-9	Strychnine	15
764-41-0	1,4-Dichloro-2-butene	15
765-34-4	Glycidylaldehyde	15
77-78-1	Dimethyl sulfate	15
98-01-1	Furfural	15
98-07-7	Benzotrichloride	15
74-88-4	Iodomethane	16
72-55-9	4,4-DDE	17
100-25-4	1,4-Dinitrobenzene	18
319-85-7	beta-BHC	18
58-89-9	gamma-BHC (Lindane)	18
205-82-3	Benzo[j]fluoranthene	19
205-99-2	Benzo(b)fluoranthene	19
207-08-9	Benzo(k)fluoranthene	19
218-01-9	Chrysene	19
56-55-3	Benzo(a)anthracene	19
72-43-5	Methoxychlor	19
309-00-2	Aldrin	20
60-57-1	Dieldrin	20

Table 2-2 Adjustments to WTP Chemicals of Potential Concern

CAS#	Constituent	Reason for Adjustment [a]
72-20-8	Endrin	20
8001-35-2	Toxaphene	20
88-85-7	2-sec-Butyl-4,6-dinitrophenol; syn Dinoseb	20
1836-75-5	Nitrofen	21
319-86-8	delta-BHC	21
50-29-3	4,4-DDT	21
72-54-8	4,4-DDD	21
93-72-1	Silvex (2,4,5-TP)	21
93-76-5	2,4,5-T	21
87-86-5	Pentachlorophenol	22
118-74-1	Hexachlorobenzene	23
319-84-6	alpha-BHC	23
76-44-8	Heptachlor	23
82-68-8	Pentachloronitrobenzene (PCNB)	23
94-75-7	2,4-D	23
2385-85-5	Mirex	24
465-73-6	Isodrin	24
1336-36-3	Polychlorinated biphenyls (PCBs)	25
11096-82-5	Aroclor-1260	26
11097-69-1	Aroclor-1254 [d]	26
11104-28-2	Aroclor-1221	26
11141-16-5	Aroclor-1232	26
12672-29-6	Aroclor-1248	26
12674-11-2	Aroclor-1016	26
53469-21-9	Aroclor-1242 [d]	26
106-42-3	p-Xylene	27
108-38-3	m-Xylene	27
95-47-6	o-Xylene	27
1330-20-7	Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations)	28
no CAS #	pH	29
no CAS #	Dibenzo(a,h)fluoranthene	30
18540-29-9	Chromium(VI)	31
10028-15-6	Ozone	32
124-38-9	Carbon dioxide	32

[a] Reason for Adjustment

1 Inorganics for which analysis was not requested by RDQO (Section 2.1.1.2).

2 Compounds identified in CHG tank vapor study eliminated; to be managed as described in Section 2.1.4.2.

3 Constituents on RDOQ starting list of 125 organics removed as feed COPCs by the TAPS revision; retained as stack emission compounds because they appear as EPA PIC (Section 2.4.2).

4 Constituents on RDOQ starting list of 125 organics removed as feed COPCs by the TAPS revision; retained as stack emission compounds because they appear as site-specific PIC (Section 2.4.2).

5 Low-toxicity constituents removed as feed COPCs by TAPs revision; retained as stack emission compounds because they appear as EPA PICs (Section 2.4.2).

Table 2-2 Adjustments to WTP Chemicals of Potential Concern

CAS#	Constituent	Reason for Adjustment [a]

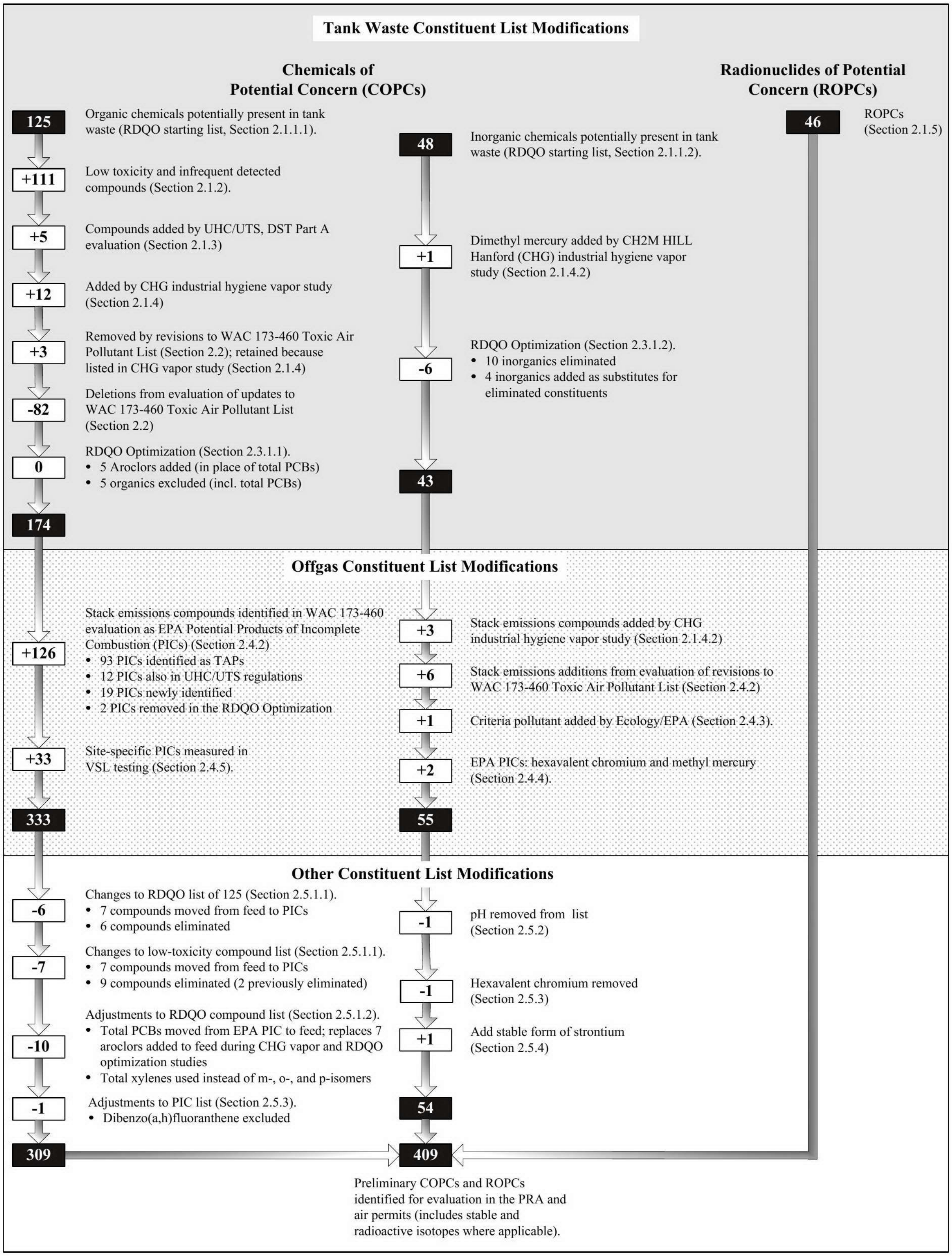
6 Low-toxicity constituent removed as feed COPC by TAPs revision; retained as stack emission compounds because it appears as site-specific PIC (Section 2.4.2).
7 Constituents on RDOQ starting list of 125 organics removed as feed COPCs by the TAPs revision; eliminated (Section 2.2.2).
8 Low-toxicity constituents removed as feed COPCs by TAPs revision; eliminated (Section 2.2.2).
9 Constituent on RDOQ starting list of 125 organics; removed as feed COPCs by TAPs revision; retained as WTP feed COPC because it appears as CHG vapor study compound (Section 2.2.2).
10 Low-toxicity constituent removed as feed COPC by TAPs revision; retained as WTP feed COPC because it appears as CHG vapor study compound (Section 2.2.2).
11 RDQO constituent removed by the RDQO Optimization Study because it's highly reactive in Hanford tank waste matrices; appears on EPA PIC list and retained as stack emission compound (Section 2.3.1.1).
12 RDQO organic constituents removed by RDQO Optimization Study (BNI 2004) because there's no suitable analytical methods for Hanford tank waste matrices (Section 2.3.1.1).
13 Inorganics removed by RDQO Optimization Study (BNI 2004) (Section 2.3.1.2).
14 Inorganic compounds removed by RDQO Optimization Study replaced by alternate inorganics (Section 2.3.1.2).
15 Constituents identified in the TAPs revision as EPA PICs and added to the stack emissions COPCs.
16 Constituents identified in the TAPs revision as site-specific PICs and added to the stack emissions COPCs.
17 Particle-bound low-toxicity feed COPC; proposed to manage as EPA PICs (CCN 097844); found in CHG vapor study and retained as feed COPC (CCN 097844) (Section 2.5.1.1).
18 Particle-bound RDQO constituents moved to EPA PIC by agreement with Ecology (CCN 097844) (Section 2.5.1.1).
19 Particle-bound low-toxicity constituents moved to EPA PIC by agreement with Ecology (CCN 097844) (Section 2.5.1.1).
20 Particle-bound RDQO constituents eliminated by agreement with Ecology (CCN 097844) (Section 2.5.1.1).
21 Particle-bound low-toxicity constituents eliminated by agreement with Ecology (CCN 097844) (Section 2.5.1.1).
22 Vapor-phase RDQO COPC; proposed to move to move to EPA PIC (CCN 097844); found in TWINS or BBI and retained as feed COPC (CCN 097844) (Section 2.5.1.1).
23 Vapor-phase compounds; moved to EPA PIC (CCN 097844) (CCN 097844) (Section 2.5.1.1).
24 Vapor-phase compounds removed (CCN 097844) (CCN 097844) (Section 2.5.1.1)
25 Total PCBs removed by Regulatory DQO Optimization Study (BNI 2004); retained as EPA PIC; moved to feed constituent by agreement with Ecology (CCN 170036) (Sections 2.3.1.1, 2.5.1.2, and 2.5.3).
26 Aroclors added by CHG vapor study and Regulatory DQO Optimization Study; eliminated by agreement with Ecology (CCN 170036) (Section 2.5.1.2).
27 Individual isomers of xylene removed; replaced with total xylenes by agreement with Ecology (CCN 170036) (Section 2.5.1.2).
28 Total xylenes moved from EPA PIC to feed by agreement with Ecology (CCN 170036) (Section 2.5.1.2).
29 pH added by Regulatory DQO Optimization Study; deleted by agreement with Ecology (CCN 170036) (Section 2.5.2).
30 Compound cannot structurally exist; removed by agreement with Ecology (CCN 139144) (Section 2.5.3).
31 Hexavalent chromium removed by RDQO Optimization Study; moved to EPA PIC; total chromium treated as if it's hexavalent for risk assessment and air permitting; eliminated (Section 2.3.1.2 and 2.5.3).
32 Stack emission compounds; address qualitatively (CCN 170036).

[b] This compound evaluated as part of the WAC 173-460 TAPs revision analysis and removed.

[c] This compound also identified for removal by RDQO Optimization Study.

[d] Compound also identified in CHG vapor study as present in tank vapors.

Figure 2-1 Identification of Constituents of Potential Concern



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BNI 2004. *Regulatory Data Quality Objectives Optimization Report,* 24590-WTP-RPT-MGT-04-001, Rev 0, February 5, 2004, Bechtel National, Inc., Richland, Washington.

CCN 011395. *Resolution of RAWP Comments from May 7, 1999 Version of the Work Plan*, Meeting Minutes, September 15, 1999, BNFL Inc., Richland, Washington.

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CCN 019721. *Elimination of Tank Waste Analysis for Picric Acid, Ammonium Perfluorooctanoate, and Methyl Isocyanate*, Letter from Suzanne Dahl, Washington State Department of Ecology, to Dr. Neal Brown, US Department of Energy, Office of River Protection, April 19, 2001.

CCN 097844. *Discuss and Resolve the Outstanding Risk Assessment Issues in the Risk Assessment Work Plan (RAWP),* Meeting Minutes from 9 September 2004 between WTP, US Environmental Protection Agency, Region 10, and Washington State Department of Ecology, in Seattle, Washington.

CCN 139144. *Removal of Dibenzo(a,h)fluoranthene from RAWP COPC List*, E-mail communication from Jerry Yokel, Washington State Department of Ecology, to John Cook, WTP, March 30, 2005.

CCN 170036. *Environmental Risk Assessment Discussions*, Meeting Minutes, March 18, 2008.

CCN 229352. *TWINS Data Evaluation (10/20/2010)*, Memorandum from Dave Blumenkranz to Lee Bostic, BNI, Inc., January 19, 2011.

3.2 Codes and Standards

40 CFR 60. *Standards of Performance for New Stationary Sources*, Current as of August 1, 2007, US Environmental Protection Agency, Washington, DC.

40 CFR 268. *Land Disposal Restrictions*, US Environmental Protection Agency, Washington, DC.

WAC 173-460. *Controls for New Sources of Toxic Air Pollutants*, Washington Administrative Code, Olympia, Washington.

3.3 Other Documents

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Ecology 2007. WA7890008967, *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste*, Part III, Operating Unit 10, Rev. 07/10, October 29, 2007, "Waste Treatment and Immobilization Plant," Attachment 51, Chapter 4, Washington State Department of Ecology, Olympia, Washington.

Ecology 2008. WA7890008967, *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste*, Operating Unit 12, Rev. 03, October 2008, "DST System/204-AR Waste Unloading Station," Dangerous Waste Permit Application Part A Form, Washington State Department of Ecology, Olympia, Washington.

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Appendix A

WTP Waste Feed COPCs Identified in the RDQO

Appendix A
WTP Waste Feed COPCs Identified in the RDQO

The preliminary list of WTP waste feed chemicals of potential concern (COPC) to be used for air permitting and risk assessment purposes was compiled using input from the regulatory data quality objectives process (RDQO) (Wiemers and others 1998). The input to the RDQO was subsequently updated based on new queries of the Tank Waste Information Network System (TWINS) database, the Underlying Hazardous Constituents (UHC) and Universal Treatment Standards (UTS) regulations (40 CFR 268.48) published by EPA, and the updated list of constituents identified in the DST Part A (Ecology 2008). The RDQO COPC compilation and update processes are described below.

Additional modifications to the list were made based on data collected by the tank vapor study (CHG 2004), (Appendix B), the revision to the list of toxic air pollutants (Appendix C), the optimization of the RDQO (Appendix D) (see the optimization report (BNI 2004) for details), and agreements reached during discussions with Ecology and the EPA (Appendix G).

A.1 WTP Waste Feed Organic COPCs Identified in the RDQO

The RDQO analytes that could plausibly be in the waste feed and of concern relative to the air and dangerous waste permitting activities were developed from a large group of regulated constituents based on (1) analytical data from samples of Hanford tank solid and liquid waste, and vapors from the headspace of the tanks, and (2) evaluation of the types of wastes that were historically stored in the tanks and the chemical constituents that may have made up these wastes.

A consolidated list of 850 chemical compounds (Table A-1) was used as the input for the original RDQO process (Wiemers and others 1998, Table B.2). This list of compounds included:

- Toxic air pollutant lists Class A (WAC 173-460-150, toxic air pollutants; known, probable, and potential human carcinogens; and acceptable source impact levels) and Class B (WAC 173-460-160, toxic air pollutants, and acceptable source impact levels)
- UHC list (40 CFR 268.48)
- UTS list (40 CFR 268.48)
- *Double-Shell Tank (DST) System Dangerous Waste Permit Application* (DOE-RL 1991) constituents, except for waste code F039. To date, no landfill leachate has been added to the tanks; therefore, these F039 compounds were not included in the RDQO database used to select the COPCs.

A brief discussion of the methods and criteria used in the RDQO to narrow the initial input list is provided below. Table A-1 identifies the source of the 850 compounds that served as the starting list input to the RDQO (Table B.2; Wiemers and others 1998). Additional details regarding this process and the compounds evaluated are provided in the RDQO (Wiemers and others 1998).

Organic analytes were retained for evaluation as potential COPCs based on the following:

- Detectability in the single-shell/double-shell tank waste
- Stability in the double-shell tank environment

- Toxicity and carcinogenicity
- Availability of SW-846 (EPA 1986) analytical methods
- Association with the operations at the Hanford Site

The result of the RDQO (Wiemers and others 1998, Table 4-4) identified 125 organic constituents. These 125 constituents in the RDQO are reproduced as Table A-2. Nineteen constituents were identified in the DQO process as regulated detected organic compounds with higher toxicity (Wiemers and others 1998, Table B.6). Table A-2 was verified to contain these 19 constituents; they are identified with an "X" in table Column 3.

Of the 850 constituents, 217 were identified as lower toxicity compounds in the RDQO process. The 217 compounds were categorized by whether Hanford tank sampling and analysis programs had detected them in the waste or vapor space. RDQO Appendix B, Table B.7, lists the detected lower toxicity compounds and Table B.22 lists the non-detected compounds (Wiemers and others 1998). Of these lower toxicity constituents, 106 were retained as part of the 125 constituents resulting from the DQO process. The remaining 111 lower toxicity constituents were removed from further consideration.

The removed 111 constituents, identified in columns 4 and 6 of Table A-3, were added back to the WTP COPC list in accordance with the agreement with Ecology and EPA (CCN 011395). Table A-3 identifies the source of the compound and indicates whether it was removed during the RDQO process.

A.2 Updates of RDQO Inputs for WTP Waste Feed COPCs

Since the RDQO was issued in 1998, there have been a number of additions and deletions to the RDQO inputs, including revisions to the UHC/UTS input list (40 CFR 268.48) and the DST Part A (Ecology 2008). In addition, the constituents detected in the tanks listed in TWINS or estimated in the BBI have been updated by 12 years of tank characterization and closure-related sampling data. The changes to the list of UHC/UTS, DST Part A and TWINS/BBI identified constituents is provided in Table A-4.

Table A-4 was used to identify new constituents potentially present in the tank waste or to eliminate constituents that a no longer have a regulatory driver and thus do not qualify as a WTP feed COPC. The UHC/UTS inputs were dispositioned as follows:

- 74 constituents identified as feed COPCs in the 1998 RDQO (see discussion in Section A.1) that appear on the updated UHC/UTS/DST Part A inputs list were retained without further evaluation (Table A-4, disposition 1)
- 49 constituents identified as low-toxicity constituents (see discussion in Section A.1) that appear on the updated UHC/UTS/DST Part A inputs list were retained (Table A-4, disposition 2)
- 5 constituents eliminated in the RDQO process and that are not low-toxicity constituents were added because they are found in the updated TWINS/BBI data (Table A-4, disposition 3)
- 1 compound (cresylic acid, CAS No. 576-26-1) was evaluated because it is identified in the DST Part A (Ecolog 2002); it was eliminated because the acid is not stable in Hanford tank waste (Table A-4, disposition 4)

- 1 compound (cresol-mixed isomers, CAS No. 1319-77-3) was eliminated because thered are no available methods for analysis in Hanford tank waste (Table A-4, disposition 5); the m-, o-, and p-isomers of cresol will be analyzed by existing methods
- 109 compounds listed in the UHC/UTS updates have not previously identified as RDQO or low-toxicity COPCs; they are not found in TWINS/BBI lists and were eliminated (Table A-4, disposition 6)
- 3 compounds previously identified as RDQO constituents were removed by the UHC/UTS updates; they are listed in TWINS/BBI and retained (Table A-4, disposition 7)
- 3 compounds previously identified as low-toxicity constituents were removed by the UHC/UTS updates; they are listed in TWINS/BBI and retained (Table A-4, disposition 8)
- 4 compounds previously identified as RDQO constituents were removed by the UHC/UTS updates; they no longer have a reglatory driver and are not listed in TWINS/BBI; therefore they were eliminated (Table A-4, disposition 9)
- 3 compounds previously identified as low-toxicity constituents were removed by the UHC/UTS updates; they no longer have a regulatory driver and are not listed in TWINS/BBI; therefore they were eliminated (Table A-4, disposition 10)
- 7 compounds were found in TWINS/BBI; they do not appear on the UHC/UTS, and DST Part A lists and therefore, were eliminated (Table A-4, disposition 11)
- 24 UHC/UTS, and DST Part A inputs to the RDQO were removed by the updates; they were eliminated

Updates to the UHC/UTS, DST Part A lists recorded in Table A-4 identified some inorganic constituents. The compounds identified in Section A.2 (Table A-4, disposition 13) did not affect the Table A-5 list of inorganics and were not further evaluated. Additional discussion of inorganic COPCs is provided below.

A.3 WTP Waste Feed Inorganic COPCs Identified in the RDQO

There were 222 inorganic constituents identified in the RDQO process (Wiemers and others 1998). The final list was determined by:

- Listing all regulated inorganic compounds and metals
- Identifying the metals or ions associated with compounds
- Consolidating the list of metals/ions
- Comparing the consolidated list to the Hanford Site inventories
- Considering the analytical methods (EPA 1986, SW-846) and their applicability to the Hanford tank waste matrices
- Assessing alternative sources of information

This process resulted in retaining 52 inorganic constituents (Table 4-7, Wiemers and others 1998) as COPCs. These inorganic COPCs are provided in Table A-5. Four of the 52 constituents were removed because unique analysis is required and alternate methods of estimating concentration exist, leaving 48 inorganic COPCs.

A.4 References

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WAC 173-460-160. *Class B Toxic Air Pollutants and Acceptable Source Impact Levels*, Washington Administrative Code, effective February 14, 1994.

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Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
100-01-6	4-Nitroaniline		x	x		x		
100-02-7	4-Nitrophenol		x	x		x		
100-21-0	Phthalic acid			x				
100-25-4	1,4-Dinitrobenzene			x		x		
100-41-4	Ethyl benzene			x	x	x		
10061-01-5	cis-1,3-Dichloropropene			x		x		
10061-02-6	trans-1,3-Dichloropropene			x		x		
100-75-4	N-Nitrosopiperidine			x		x		
101-14-4	4,4'-Methylenebis(2-chloroaniline)	x		x		x		
101-27-9	Barban					x		
101-55-3	4-Bromophenylphenyl ether			x		x		
1024-57-3	Heptachlor Epoxide			x		x		
1031-07-8	Endosulfan Sulfate			x		x		
105-67-9	2,4-Dimethylphenol			x		x		
10595-95-6	N-Nitrosomethylethylamine	x		x		x		
10605-21-7	Carbendazim					x		
106-44-5	4-Methylphenol (p-Cresol)			x	x	x		
106-46-7	1,4-Dichlorobenzene	x		x		x		
106-47-8	4-Chloroaniline			x		x		
106-93-4	Ethylene dibromide	x		x		x		
107-02-8	Acrolein		x	x		x		
107-05-1	3-Chloropropene		x	x		x		
107-06-2	1,2-Dichloroethane	x		x	x	x		
107-12-0	Propionitrile			x		x		
107-13-1	Acrylonitrile	x		x		x		
108-10-1	4-Methyl-2-pentanone		x	x	x	x		
108-39-4	m-Cresol		x	x		x		
108-88-3	Toluene		x	x	x	x		
108-90-7	Chlorobenzene		x	x	x	x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
108-94-1	Cyclohexanone		x	x	x	x		
108-95-2	Phenol		x	x		x		
110-75-8	2-Chloroethyl vinyl ether			x		x		
110-86-1	Pyridine		x	x	x	x		
111-44-4	Bis(2-chloroethyl) ether	x		x		x		
1114-71-2	Pebulate			x		x		
111-91-1	Bis(2-Chloroethoxy)methane			x		x		
1129-41-5	Metolcarb (3-methylcholanthrene)					x		
114-26-1	Propoxur		x	x		x		
117-84-0	Di-n-octylphthalate			x		x		
118-74-1	Hexachlorobenzene	x		x		x		
120-12-7	Anthracene			x		x		
120-58-1	Isosafrole			x		x		
120-82-1	1,2,4-Trichlorobenzene		x	x		x		
120-83-2	2,4-Dichlorophenol			x		x		
121-14-2	2,4-Dinitrotoluene		x	x	x	x		
121-44-8	Triethylamine		x	x		x		
122-39-4	N,N-Diphenylamine		x	x		x		
122-42-9	Propham					x		
122-66-7	1,2-Diphenylhydrazine	x		x		x		
123-91-1	1,4-Dioxan	x		x		x		
124-48-1	Dibromochloromethane			x		x		
126-72-7	Tris(2,3-dibromopropyl) phosphate			x		x		
126-98-7	2-Methyl-2-propenenitrile		x	x		x		
126-99-8	Chloroprene	x		x		x		
127-18-4	1,1,2,2-Tetrachloroethene	x		x	x	x		
129-00-0	Pyrene			x		x		
131-11-3	Dimethyl phthalate		x	x		x		
1330-20-7	Xylene			x	x	x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
1336-36-3	Polychlorinated biphenyls (PCBs)	x		x		x	x	
140-57-8	Aramite			x		x		
141-78-6	Acetic acid ethyl ester		x	x	x	x		
143-50-0	Kepone			x		x		
1563-38-8	Carbofuran phenol					x		
1563-66-2	Carbofuran		x	x		x		
156-60-5	1,2-trans-Dichloroethene			x	x	x		
1646-88-4	Aldicarb sulfone			x		x		
16752-77-5	Methomyl		x	x		x		
16984-48-8	Fluoride		x	x		x		x
17804-35-2	Benomyl		x	x		x		
18496-25-8	Sulfide			x		x		
191-24-2	Benzo(g,h,i)perylene			x		x		
192-65-4	Dibenzo[a,e]pyrene	x		x		x		
1929-77-7	Vernolate			x		x		
193-39-5	Indeno(1,2,3-cd)pyrene	x		x		x		
2008-41-5	Butylate			x		x		
2032-65-7	Methiocarb			x		x		
205-99-2	Benzo(b)fluoranthene	x		x		x		
206-44-0	Fluoranthene			x		x		
207-08-9	Benzo(k)fluoranthene	x		x		x		
208-96-8	Acenaphthylene			x		x		
218-01-9	Chrysene			x		x		
2212-67-1	Molinate			x		x		
22781-23-3	Bendiocarb			x		x		
2303-17-5	Triallate					x		
23135-22-0	Oxamy			x		x		
23422-53-9	Formetanate hydrochloride					x		
23564-05-8	Thiophanate-methyl					x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
23950-58-5	Pronamide			x		x		
2631-37-0	Promecarb					x		
298-00-0	Methyl parathion		x	x		x		
298-02-2	Phorate		x	x		x		
298-04-4	Disulfoton		x	x		x		
309-00-2	Aldrin	x		x		x		
315-18-4	Mexacarbate			x		x		
319-84-6	alpha-BHC	x		x		x		
319-85-7	beta-BHC	x		x		x		
319-86-8	delta-BHC			x		x		
33213-65-9	Endosulfan II			x		x		
3424-82-6	o,p'-DDE (2,4'-DDE)			x		x		
465-73-6	Isodrin			x		x		
50-29-3	4,4-DDT	x		x		x		
50-32-8	Benzo(a)pyrene	x		x		x		
510-15-6	Chlorobenzilate	x		x		x		
51-28-5	2,4-Dinitrophenol		x	x		x		
52-85-7	Famphur			x		x		
52888-80-9	Prosulfocarb					x		
53-19-0	o,p'-DDD (2,4'-DDD)			x		x		
534-52-1	4,6-Dinitro-o-cresol		x	x		x		
53-70-3	Dibenz[a,h]anthracene	x		x		x		
53-96-3	2-Acetylaminofluorene	x		x		x		
541-73-1	1,3-Dichlorobenzene			x		x		
55-18-5	N-Nitrosodiethylamine	x		x		x		
55285-14-8	Carbosulfan					x		
56-23-5	Carbon tetrachloride	x		x	x	x		
56-38-2	Parathion		x	x		x		
56-49-5	3-Methylcholanthrene			x		x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
56-55-3	Benzo(a)anthracene	x		x		x		
57-12-5	Cyanide		x	x		x		
57-12-5a	Cyanide (amenable)			x		x		
57-47-6	Physostigmine					x		
57-64-7	Physostigmine salicylate					x		
57-74-9	Chlordane	x		x		x		
58-89-9	gamma-BHC (Lindane)	x		x		x		
58-90-2	2,3,4,6-Tetrachlorophenol			x		x		
59-50-7	4-Chloro-3-methylphenol			x		x		
59669-26-0	Thiodicarb					x		
59-89-2	N-Nitrosomorpholine	x		x		x		
60-11-7	p-Dimethylaminoazobenzene		x	x		x		
60-29-7	Ethyl ether		x	x	x	x		
60-57-1	Dieldrin	x		x		x		
606-20-2	2,6-Dinitrotoluene			x		x		
608-93-5	Pentachlorobenzene			x		x		
621-64-7	N-Nitroso-di-n-propylamine	x		x		x		
62-44-2	Phenacetin			x		x		
62-53-3	Aniline	x	x	x		x		
62-75-9	N-Nitroso-N,N-dimethylamine	x		x		x		
630-20-6	1,1,1,2-Tetrachloroethane			x	x	x		
63-25-2	Carbaryl		x	x		x		
64-00-6	m-Cumenyl methylcarbamate					x		
66-27-3	Methyl methanesulfonate			x		x		
67-56-1	Methyl alcohol		x	x	x	x		
67-64-1	2-Propanone (Acetone)		x	x	x	x		
67-66-3	Chloroform	x		x	x	x		
67-72-1	Hexachloroethane		x	x	x	x		
71-36-3	n-Butyl alcohol		x	x	x	x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
71-43-2	Benzene	x		x	x	x		
71-55-6	1,1,1-Trichloroethane		x	x	x	x		
72-20-8	Endrin		x	x		x		
72-43-5	Methoxychlor		x	x		x		
72-54-8	4,4-DDD			x		x		
72-55-9	4,4-DDE			x		x		
7421-93-4	Endrin aldehyde			x		x		
7439-92-1	Lead			x		x		
7439-97-6	Mercury			x	x	x		
7440-02-0	Nickel			x		x	x	x
7440-22-4	Silver		x	x	x	x		
7440-28-0	Thallium			x		x		
7440-36-0	Antimony			x		x		
7440-38-2	Arsenic			x	x	x		
7440-39-3	Barium			x	x	x		x
7440-41-7	Beryllium			x		x		
7440-43-9	Cadmium	x		x	x	x		
7440-47-3	Chromium		x	x		x	x	x
7440-62-2	Vanadium			x		x		
7440-66-6	Zinc			x		x		x
74-83-9	Bromomethane		x	x		x		
74-87-3	Chloromethane		x	x		x		
74-88-4	Iodomethane		x	x		x		
74-95-3	Dibromomethane			x		x		
75-00-3	Chloroethane		x	x		x		
75-01-4	1-Chloroethene	x		x		x		
75-05-8	Acetonitrile		x	x		x		
75-09-2	Dichloromethane (Methylene Chloride)	x		x	x	x		
75-15-0	Carbon disulfide		x	x	x	x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
75-21-8	Oxirane	x		x		x		
75-25-2	Tribromomethane	x		x		x		
75-27-4	Bromodichloromethane			x		x		
75-34-3	1,1-Dichloroethane		x	x		x		
75-35-4	1,1-Dichloroethene		x	x		x		
75-69-4	Trichlorofluoromethane		x	x		x		
75-71-8	Dichlorodifluoromethane		x	x		x		
759-94-4	EPTC			x		x		
76-01-7	Pentachloroethane			x		x		
76-13-1	1,2,2-Trichlorotrifluoroethane		x	x	x	x		
76-44-8	Heptachlor	x		x		x		
77-47-4	Hexachlorocyclopentadiene		x	x		x		
7782-49-2	Selenium			x	x	x		
78-83-1	2-Methylpropyl alcohol		x	x	x	x		
78-87-5	1,2-Dichloropropane	x		x		x		
789-02-6	o,p'-DDT (2,4'-DDT)			x		x		
78-93-3	2-Butanone		x	x	x	x		
79-00-5	1,1,2-Trichloroethane		x	x	x	x		
79-01-6	1,1,2-Trichloroethylene	x		x	x	x		
79-06-1	Acrylamide	x		x		x		
79-34-5	1,1,2,2-Tetrachloroethane		x	x		x		
8001-35-2	Toxaphene	x		x		x		
80-62-6	Methyl methacrylate		x	x		x		
82-68-8	Pentachloronitrobenzene (PCNB)		x	x		x		
83-32-9	Acenaphthene			x		x		
84-66-2	Diethyl phthalate		x	x		x		
84-74-2	Di-n-butylphthalate		x	x		x		
85-01-8	Phenanthrene			x		x		
85-44-9	Phthalic anhydride		x	x		x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
85-68-7	Butylbenzylphthalate			x		x		
86-30-6	N-Nitrosodiphenylamine	x		x		x		
86-73-7	Fluorene			x		x		
87-65-0	2,6-Dichlorophenol			x		x		
87-68-3	Hexachlorobutadiene		x	x	x	x		
87-86-5	Pentachlorophenol	x		x		x		
88-06-2	2,4,6-Trichlorophenol	x		x		x		
88-74-4	2-Nitroaniline			x		x		
88-75-5	2-Nitrophenol			x		x		
88-85-7	2-sec-Butyl-4,6-dinitrophenol; syn Dinoseb			x		x		
91-20-3	Naphthalene		x	x		x		
91-58-7	2-Chloronaphthalene			x		x		
91-59-8	2-Napthylamine			x		x		
91-80-5	Methapyrilene			x		x		
924-16-3	N-Nitrosodi-n-butylamine	x		x		x		
92-67-1	4-Aminobiphenyl	x		x		x		
930-55-2	N-Nitrosopyrrolidine			x		x		
93-72-1	Silvex (2,4,5-TP)			x		x		
93-76-5	2,4,5-T		x	x		x		
94-59-7	Safrole			x		x		
94-75-7	2,4-D	x		x		x		
95-48-7	o-Cresol		x	x	x	x		
95-50-1	1,2-Dichlorobenzene		x	x	x	x		
95-57-8	2-Chlorophenol			x		x		
95-94-3	1,2,4,5-Tetrachlorobenzene			x		x		
95-95-4	2,4,5-Trichlorophenol		x	x	x	x		
959-98-8	Endosulfan I			x		x		
96-12-8	1,2-Dibromo-3-chloropropane		x	x		x		
96-18-4	1,2,3-Trichloropropane		x	x		x		

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
97-63-2	Ethyl methacrylate			x		x		
98-86-2	Acetophenone [3]		x	x		x		
98-87-3	Benzal chloride			x		x		
98-95-3	Nitrobenzene		x	x	x	x		
99-55-8	5-Nitro-o-toluidine			x		x		
106-42-3	p-Xylene			x	x	x		
108-38-3	m-Xylene			x	x	x		
110-80-5	2-Ethoxyethanol		x		x			
1319-77-3	Cresol (mixed isomers)				x			
27154-33-2	Trichlorofluoroethane				x			
95-47-6	o-Xylene			x	x	x		
NA1	Chlorinated fluorocarbons, N.O.S.				x			
101-90-6	Diglycidyl resorcinol ether	x		x				
117-81-7	Bis(2-ethylhexyl) phthalate	x		x		x		
134-32-7	alpha-Naphthylamine	x		x				
139-65-1	4,4'-Thiodianiline	x		x				
1746-01-6	TCDD (Dioxin/Furan Indicator)	x		x				
106-50-3	p-Phenylenediamine		x	x				
123-31-9	Hydroquinone		x	x				
1314-62-1	Vanadium pentoxide		x		x			
504-29-0	2-Aminopyridine		x	x				
528-29-0	Dinitrobenzene, all isomers		x	x				
54-11-5	Nicotine		x	x				
75-52-5	Nitromethane		x	x				
1024-57-D	Heptachlor epoxide isomers			x				
108-60-1	Bis(2-Chloroisopropyl) ether			x		x		
11141-16-5	PCB-1232			x				
1134-23-2	Cycloate			x				
12672-29-6	PCB-1248			x				

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
135-88-6	N-Phenyl-2-napthylamine			x				
137-30-4	Ziram			x		x		
1888-71-7	Hexachloropropylene			x		x		
30402-14-3D	Tetrachlorodibenzofurans			x				
30402-15-4D	Pentachlorodibenzofurans			x				
34465-46-8D	Hexachlorodibenzo-p-dioxins			x				
36088-22-9D	Pentachlorodibenzo-p-dioxins			x				
41903-57-5D	Tetrachlorodi-benzo-p-dioxins			x				
55406-53-6	3-Iodo-2-propynyl n-butylcarbamate			x				
55684-94-1D	Hexachlorodibenzofurans			x				
57-74-D	Chlordane (alpha and gamma isomers)			x				
119-38-0	Isolan					x		
17702-57-7	Formparanate					x		
22961-82-6	Bendiocarb phenol					x		
26419-73-8	Tirpate					x		
30558-43-1	Oxamyl-oxime (A2213)					x		
5952-26-1	Diethylene glycol, dicarbamate					x		
644-64-4	Dimetilan					x		
95-54-5	1,2-Phenylenediamine					x		
HxCDD	HxCDDs (All Hexachlorodibenzo-p-dioxins)					x		
HxCDF	HxCDFs (All Hexachlorodibenzofurans)					x		
PeCDD	PeCDDs (All Pentachlorodibenzo-p-dioxins)					x		
PeCDF	PeCDFs (All Pentachlorodibenzofurans)					x		
TCDD	TCDDs (All Tetrachlorodibenzo-p-dioxins)					x		
TCDF	TCDFs (All Tetrachlorodibenzofurans)					x		
NA31	DW, WP02, persistent DW halogenated hydrocarbons				x			
NA32	EHW, WP01, persistent DW halogenated hydrocarbons				x			
NA33	DW, WT02, toxic dangerous waste				x			

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
NA34	EHW, WT01, toxic dangerous waste				x			
100-00-5	p-Nitrochlorobenzene [1]		x					
10025-67-9	Sulfur monochloride		x					
10025-87-3	Phosphorus oxychloride		x					
10026-13-8	Phosphorus pentachloride		x					
10035-10-6	Hydrogen bromide		x					
100-37-8	Diethylaminoethanol		x					
100-42-5	Styrene		x					
100-44-7	Benzyl chloride		x					
10049-04-4	Chlorine dioxide		x					
100-61-8	N-Methylbenzenamine		x					
100-63-0	Phenylhydrazine		x					
100-74-3	N-Ethylmorpholine		x					
10102-43-9	Nitric oxide		x					
101-68-8	Methylene bis(phenyl isocyanate)		x					
101-77-9	4,4-Methylene dianiline	x						
101-80-4	4,4'-Diaminodiphenyl ether	x						
101-84-8	Diphenyl ether		x					
10210-68-1	Cobalt carbonyl as Co		x					
102-54-5	Dicyclopentadienyl iron		x					
102-81-8	2-N-Dibutylaminoethanol		x					
10294-33-4	Boron tribromide		x					
105-46-4	sec-Butyl acetate		x					
105-60-2	Caprolactam, vapor		x					
105-60-2a	Caprolactam, dust		x					
106-35-4	3-Heptanone		x					
106-49-0	p-Toluidine		x					
106-51-4	p-Benzoquinone		x					
106-87-6	Vinyl cyclohexene dioxide		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
106-88-7	1,2-Epoxybutane		x					
106-89-8	Epichlorohydrin	x						
106-92-3	Allyl glycidyl ether		x					
106-97-8	Butane		x					
106-99-0	1,3-Butadiene	x						
107-07-3	Ethylene chlorohydrin		x					
107-15-3	Ethylene diamine		x					
107-18-6	2-Propen-1-ol		x					
107-19-7	Propargyl alcohol		x					
107-20-0	Chloroacetaldehyde		x					
107-21-1	Ethylene glycol		x					
107-30-2	Chloromethyl methyl ether	x						
107-31-3	Formic acid, methyl ester		x					
107-41-5	Hexylene glycol		x					
107-49-3	Tetraethyl pyrophosphate		x					
107-66-4	Dibutylphosphate		x					
107-87-9	2-Pentanone		x					
107-98-2	Propylene glycol monomethyl ether		x					
108-03-2	1-Nitropropane		x					
108-05-4	Acetic acid vinyl ester		x					
108-11-2	Methyl isobutyl carbinol		x					
108-18-9	Diisopropylamine		x					
108-20-3	Bis(isopropyl) ether		x					
108-21-4	Isopropyl acetate		x					
108-24-7	Acetic anhydride		x					
108-31-6	Maleic anhydride (2,5-Furandione)		x					
108-43-0	Chlorophenols	x						
108-44-1	m-Toluidine		x					
108-46-3	Resorcinol (1,3-Benzenediol)		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
108-83-8	Diisobutyl ketone		x					
108-84-9	sec-Hexyl acetate		x					
108-87-2	Methylcyclohexane		x					
108-91-8	Cyclohexylamine		x					
108-93-0	Cyclohexanol		x					
108-98-5	Thiophenol		x					
109-59-1	Isopropoxyethanol		x					
109-60-4	n-Propyl acetate		x					
109-66-0	n-Pentane		x					
109-73-9	n-Butylamine		x					
109-79-5	n-Butyl mercaptan		x					
109-86-4	2-Methoxyethanol		x					
109-87-5	Methylal		x					
109-89-7	Diethylamine		x					
109-94-4	Ethyl formate		x					
109-99-9	Tetrahydrofuran		x					
110-12-3	5-Methyl-2-hexanone		x					
110-19-0	Isobutyl acetate		x					
110-43-0	2-Heptanone		x					
110-49-6	2-Methoxyethyl acetate		x					
110-54-3	n-Hexane		x					
110-54-3D	Hexane, other isomers		x					
110-62-3	n-Valeraldehyde		x					
110-82-7	Cyclohexane		x					
110-83-8	Cyclohexene		x					
110-91-8	Morpholine		x					
111-15-9	2-Ethoxyethyl acetate		x					
111-30-8	Glutaraldehyde		x					
111-40-0	Diethylene triamine		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
111-42-2	Diethanolamine		x					
111-46-6D	Glycol ethers		x					
111-65-9	n-Octane		x					
111-76-2	2-Butoxyethanol		x					
111-84-2	n-Nonane		x					
1120-71-4	1,3-Propane sultone	x						
115-29-7	Endosulfan		x					
115-86-6	Triphenyl phosphate		x					
115-90-2	Fensulfothion		x					
117-79-3	2-Aminoanthraquinone	x						
118-52-5	1,3-Dichloro-5,5-Dimethyl hydantoin		x					
118-96-7	2,4,6-Trinitrotoluene		x					
1189-85-1	tert-Butyl chromate, as CrO3		x					
119-90-4	3,3'-Dimethoxybenzidine	x						
119-93-7	3,3'-Dimethylbenzidine.	x						
12079-65-1	Manganese cyclopentadienyl tricarbonyl		x					
120-80-9	Catechol		x					
12108-13-3	Methylcyclopentadienylmanganese tricarbonyl		x					
12125-02-9	Ammonium chloride (fume)		x					
121-45-9	Trimethyl phosphite		x					
121-69-7	Dimethylaniline		x					
121-75-5	Malathion		x					
121-82-4	Cyclonite		x					
122-60-1	Phenyl glycidyl ether		x					
123-19-3	4-Heptanone		x					
123-38-6	n-Propionaldehyde		x					
123-42-2	Diacetone alcohol		x					
123-51-3	3-Methyl-1-butanol		x					
123-86-4	Acetic acid n-butyl ester		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
123-92-2	Isoamyl acetate		x					
124-40-3	Dimethylamine		x					
12604-58-9	Ferrovanadium dust		x					
126-73-8	Tributyl phosphate		x					
126-85-2	Nitrogen mustard N-oxide	x						
127-19-5	N,N-Dimethylacetamide		x					
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol		x					
129-15-7	2-Methyl-1-nitroanthraquinone	x						
1300-73-8	Xylidine		x					
1303-86-2	Boron oxide		x					
1303-96-4Ca	Borates, anhydrous		x					
1303-96-4Cb	Borates, pentahydrate		x					
1303-96-4Cc	Borates, decahydrate		x					
1304-82-1	Bismuth telluride		x					
1305-62-0	Calcium hydroxide		x					
1305-78-8	Calcium oxide		x					
1309-37-1	Iron oxide fume, Fe2O3 as Fe		x					
1309-48-4	Magnesium oxide fume		x					
1309-64-4	Antimony trioxide, as Sb		x					
1310-58-3	Potassium hydroxide		x					
1310-73-2	Sodium hydroxide		x				x	
13121-70-5	Cyhexatin		x					
1314-13-2	Zinc oxide, fume		x					
1314-20-1	Thorium dioxide	x						
1314-80-3	Phosphorus pentasulfide		x					
1319-77-3a	Cresols, syn Cresylic acid		x					
1321-64-8	Pentachloronaphthalene		x					
1321-65-9	Trichloronaphthalene		x					
1321-74-0	Divinyl benzene		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
132-64-9	Dibenzofuran	x						
133-06-2	Captan		x					
1332-21-4	Asbestos (fiberous)	x						
1333-86-4	Carbon black		x					
1335-87-1	Hexachloronaphthalene		x					
1335-88-2	Tetrachloronaphthalene		x					
1338-23-4	Methyl ethyl ketone peroxide		x					
133-90-4	Chloramben		x					
13463-40-6	Iron pentacarbonyl, as Fe		x					
13494-80-9C	Tellurium & compounds as Te		x					
135-20-6	Cupferron	x						
13530-65-9	Zinc chromates		x					
13552-44-8	4,4-Methylenedianiline dihydrochloride	x						
136-78-7	Sesone		x					
137-05-3	Methyl-2-cyanoacrylate		x					
137-26-8	Thiram		x					
138-22-7	n-Butyl lactate		x					
13838-16-9	Enflurane		x					
1395-21-7	Subtilisins		x					
139-91-3	5-(Morpholinomethyl)-3-amino-2-oxazolidinone (furaltudone)	x						
140-88-5	Ethylacrylate		x					
141-32-2	Butylacrylate		x					
141-43-5	Ethanolamine		x					
141-66-2	Dicrotophos		x					
141-79-7	4-Methyl-3-penten-2-one		x					
142-64-3	Piperazine dihydrochloride		x					
14265-44-2	Phosphate							x
14280-30-9	Hydroxide						x	

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
142-82-5	n-Heptane		x					
144-62-7	Oxalic acid		x					
14484-64-1	Ferbam		x					
1477-55-0	m-Xylene-a,a'-diamine		x					
14797-65-0	Nitrite						x	x
148-01-6	Dinitolamide		x					
14808-79-8	Sulfate							x
14977-61-8	Chromylchloride		x					
150-76-5	4-Methoxyphenol		x					
151-56-4	Ethyleneimine		x					
151-67-7	Halothane		x					
156-62-7	Calcium cyanamide		x					
1582-09-8	Trifluralin		x					
1615-80-1	N,N'-Diethylhydrazine	x						
16219-75-3	Ethylidene norbornene		x					
1634-04-4	Methyl tert-butyl ether		x					
16842-03-8	Cobalt hydrocarbonyl		x					
16887-00-6	Chloride						x	x
1694-09-3	Benzyl violet 4b	x						
17702-41-9	Decaborane		x					
1836-75-5	Nitrofen	x						
18540-29-9	Chromium, hexavalent metal and compounds [2]	x						
189-55-9	Dibenzo[a,i]pyrene	x						
189-64-0	Dibenzo[a,h]pyrene	x						
1912-24-9	Atrazine		x					
191-30-0	Dibenzo(a,l)pyrene	x						
1918-02-1	Picloram		x					
19287-45-7	Diborane		x					
1929-82-4	Nitrapyrin		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
19624-22-7	Pentaborane		x					
2039-87-4	o-Chlorostyrene		x					
205-82-3	Benzo[j]fluoranthene	x						
20816-12-0	Osmium tetroxide		x					
2104-64-5	EPN		x					
21087-64-9	Metribuzin		x					
21351-79-1	Cesium hydroxide		x					
2179-59-1	Allyl propyl disulfide		x					
22224-92-6	Fenamiphos		x					
2234-13-1	Octachloronaphthalene		x					
2238-07-5	Diglycidyl ether		x					
224-42-0	Dibenz[a,j]acridine	x						
226-36-8	Dibenz[a,h]acridine	x						
2385-85-5	Mirex	x						
2425-06-1	Captafol		x					
2426-08-6	n-Butyl glycidyl ether		x					
2465-27-2	Auramine (technical grade)	x						
25013-15-4	Vinyl toluene		x					
2551-62-4	Sulfur hexafluoride		x					
25551-13-7	Trimethyl benzene [3]		x					
25639-42-3	Methylcyclohexanol		x					
26140-60-3	Terphenyls		x					
2646-17-5	Oil orange SS	x						
26628-22-8	Sodium azide		x					
26952-21-6	Iso-ocytl alcohol		x					
2698-41-1	o-Chlorobenylidene malonitrile		x					
2699-79-8	Sulfuryl fluoride		x					
28434-86-8	3,3'-Dichloro-4,4'-diaminodiphenyl ether	x						
287-92-3	Cyclopentane		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
29191-52-4	Anisidine (o-,p- isomers)		x					
2921-88-2	Chlorpyrifos		x					
2971-90-6	Clopidol		x					
299-84-3	Ronnel		x					
299-86-5	Crufomate		x					
300-76-5	Naled		x					
301-04-2	Lead acetate	x						
302-01-2	Hydrazine	x						
302-70-5	Nitrogen mustard N-oxide hydrochloride	x						
3068-88-0	B-Butyrolactone	x						
314-40-9	Bromacil		x					
330-54-1	Diuron		x					
3333-52-6	Tetramethyl succinonitrile		x					
333-41-5	Diazinon		x					
334-88-3	Diazomethane		x					
3383-96-8	Temephos		x					
34590-94-8	Dipropylene glycol methyl ether		x					
353-50-4	Carbon oxyfluoride		x					
35400-43-2	Sulprofos		x					
3547-04-4	DDE (p,p'-Dichlorodiphenyldichloroethylene)	x						
3687-31-8	Lead arsenate, as Pb3 (A2O4)2		x					
3689-24-5	Tetraethyldithiopyrophosphate (TEDP)		x					
3697-24-3	5-Methylchrysene	x						
3761-53-3	Ponceau MX	x						
3812-32-6	Carbonate							x
3825-26-1	Ammonium perfluorooctanoate		x					
4016-14-2	Isopropyl glycidyl ether (IGE)		x					
4098-71-9	Isophorone diisocyanate		x					
4170-30-3	2-Butenaldehyde		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
420-04-2	Cyanamide		x					
460-19-5	Cyanogen		x					
463-51-4	Ketene		x					
463-58-1	Carbon oxide sulfide (COS)		x					
4685-14-7	Paraquat		x					
479-45-8	Tetryl		x					
50-00-0	Formaldehyde	x						
506-77-4	Cyanogen chloride		x					
509-14-8	Tetranitromethane		x					
5124-30-1	Methylene-bis-(4-cyclo-hexylisocyanate)		x					
51-79-6	Ethyl carbamate (urethane)		x					
531-82-8	N-(4-(5-Nitro-2-furyl)-2-thiazolyl)acetamide	x						
532-27-4	a-Chloroacetophenone		x					
540-59-0	1,2-Dichloroethylene		x					
540-73-8	1,2-Dimethylhydrazine	x						
540-84-1	2,2,4-Trimethylpentane		x					
540-88-5	tert-Butyl acetate		x					
541-85-5	Ethyl amyl ketone		x					
542-75-6	1,3-Dichloropropene		x					
542-88-1	Dichloromethyl ether	x						
542-92-7	Cyclopentadiene		x					
552-30-7	Trimellitic anhydride		x					
55-38-9	Fenthion		x					
555-84-9	1-(5-Nitrofurfurylidene)amino)-2-imidazolidinone	x						
55-63-0	Nitroglycerin		x					
556-52-5	Glycidol		x					
55720-99-5	Chlorinated diphenyl oxide		x					
55738-54-0	trans-2((Dimethylamino)methylimino)-5-(2-(5-nitro-2-furyl) vinyl-1,3,4-oxadiazole	x						
558-13-4	Carbon tetrabromide		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
563-12-2	Ethion		x					
563-80-4	3-Methyl-2-butanone		x					
5714-22-7	Sulfur pentafluoride		x					
57-14-7	1,1-Dimethylhydrazine		x					
57-24-9	Strychnine		x					
57-57-8	B-Propiolactone		x					
583-60-8	o-Methylcyclohexanone		x					
584-84-9	2,4-Toluene diisocyanate	x						
591-78-6	2-Hexanone		x					
592-62-1	Methyl azoxymethyl acetate	x						
59355-75-8	Methyl acetylene-propadiene mixture (MAPP)		x					
593-60-2	Vinyl bromide		x					
594-42-3	Perchloromethyl mercaptan		x					
594-72-9	1,1-Dichloro-1-nitroethane		x					
59-87-0	Nitrofurazone	x						
600-25-9	1-Chloro-1-nitropropane		x					
602-87-9	5-Nitroacenaphthene	x						
603-34-9	Triphenyl amine		x					
60-34-4	Methylhydrazine		x					
60-35-5	Acetamide		x					
613-35-4	N,N-Diacetylbenzidine	x						
615-53-2	N-Nitroso-N-methylurethane	x						
61-82-5	Amitrole	x						
624-83-9	Methyl isocyanate		x					
626-17-5	m-Phthalodinitrile		x					
626-38-0	sec-Amyl acetate		x					
627-13-4	Nitric acid, propyl ester		x					
62-73-7	Dichlorvas		x					
62-74-8	Fluoroacetic acid, sodium salt (Fratol)		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
628-63-7	n-Amyl acetate		x					
628-96-6	Ethylene glycol dinitrate		x					
636-21-5	o-Toluidine hydrochloride	x						
638-21-1	Phenylphosphine		x					
63-92-3	Phenoxybenzamine hydrochloride	x						
64091-91-4	4-(Methylnitrosamino)-1-(3-pyridyl)-1-butanone	x						
64-17-5	Ethyl alcohol		x					
64-18-6	Formic acid		x					
64-19-7	Acetic acid		x					
6423-43-4	Propylene glycol dinitrate		x					
64-67-5	Diethyl sulfate		x					
67-45-8	Furazolidone	x						
67-63-0	2-Propyl alcohol		x					
680-31-9	Hexamethylphosphoramide	x						
68-11-1	Thioglycolic acid		x					
68-12-2	Dimethylformamide		x					
681-84-5	Methyl silicate		x					
684-16-2	Hexafluoroacetone		x					
68476-85-7	Liquified petroleum gas		x					
684-93-5	N-Nitroso-N-methylurea		x					
6923-22-4	Monocrotophos		x					
696-28-6	Dichlorophenylarsine	x						
71-23-8	n-Propyl alcohol		x					
7429-90-5	Aluminum		x				x	x
7429-90-5Ca	Aluminum, Al alkyls		x					
7429-90-5Cb	Aluminum, as AL pyro powders		x					
7429-90-5Cc	Aluminum, as Al soluble salts		x					
7429-90-5Ce	Aluminum, as Al welding fumes		x					
7439-89-6	Iron						x	x

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
7439-89-6D	Iron salts, soluble as Fe		x					
7439-92-1D	Lead compounds	x						
7439-96-5	Manganese						x	
7439-96-5Ca	Manganese dust & compounds		x					
7439-96-5Cb	Manganese fume		x					
7439-97-6Ca	Mercury, Aryl & inorganic cmpd		x					
7439-97-6Cb	Mercury, as Hg Alkyl compounds		x					
7439-97-6Cc	Mercury, vapors except alkyl		x					
7439-98-7Ca	Molybdenum, insoluble cpds		x					
7439-98-7Cb	Molybdenum, as Mo soluble cpds		x					
7440-02-0C	Nickel compounds	x						
7440-06-4	Platinum, metal		x					
7440-06-4C	Platinum, soluble salts as Pt		x					
7440-09-7	Potassium							x
7440-16-6	Rhodium Metal		x					
7440-16-6Ca	Rhodium, insoluble compounds		x					
7440-16-6Cb	Rhodium, soluble compounds		x					
7440-21-3	Silicon							x
7440-22-4Da	Silver, soluble compounds as Ag		x					
7440-23-5	Sodium						x	x
7440-25-7C	Tantalum, metal & oxide dusts		x					
7440-28-0C	Thallium, soluble compounds, Tl		x					
7440-31-5	Tin, oxide & inorganic except SnH4		x					
7440-31-5a	Tin, metal		x					
7440-31-5C	Tin, organic compounds, as Sn		x					
7440-33-7Ca	Tungsten, insoluble compounds		x					
7440-33-7Cb	Tungsten, soluble compounds		x					
7440-36-0C	Antimony & compounds as Sb		x					
7440-38-2C	Arsenic and inorganic arsenic compounds	x						

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
7440-39-3Da	Barium, soluble compounds Ba		x					
7440-41-7a	Beryllium powder	x						
7440-42-8	Boron							x
7440-47-3Db	Chromium (II) compounds, as Cr		x					
7440-47-3Dc	Chromium (III) compounds, Cr		x					
7440-48-4a	Cobalt as Co metal dust and fume		x					
7440-50-8	Copper		x					
7440-50-8C	Copper, Dusts and mists, as Cu		x					
7440-58-6	Hafnium		x					
7440-61-1C	Uranium, insoluble & soluble		x					
7440-65-5C	Yttrium, metal and compounds as Y		x					
7440-67-7	Zirconium						x	x
7440-67-7C	Zirconium compounds, as Zr		x					
7440-69-9	Bismuth							x
7440-70-2	Calcium							x
7440-74-6C	Indium, & compounds as In		x					
7446-27-7	Lead phosphate	x						
74-89-5	Methylamine		x					
74-90-8	Hydrogen cyanide		x					
74-93-1	Thiomethanol		x					
74-96-4	Ethyl bromide		x					
74-97-5	Bromochloromethane		x					
74-99-7	Methylacetylene		x					
75-04-7	Ethylamine		x					
75-07-0	Acetaldehyde	x						
75-08-1	Ethyl mercaptan		x					
75-12-7	Formamide		x					
75-31-0	Isopropylamine		x					
75-43-4	Dichlorofluoromethane		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
75-44-5	Phosgene		x					
75-45-6	Chlorodifluoromethane		x					
75-47-8	Iodoform		x					
75-50-3	Trimethylamine		x					
7550-45-0	Titanium tetrachloride		x					
7553-56-2	Iodine		x					
75-55-8	2-Methylaziridine		x					
75-56-9	Propylene oxide	x						
75-61-6	Difluorodibromomethane		x					
75-63-8	Trifluorobromomethane		x					
75-65-0	2-Methyl-2-propanol		x					
7572-29-4	Dichloroacetylene		x					
75-74-1	Tetramethyl lead, as Pb		x					
7580-67-8	Lithium hydride		x					
759-73-9	N-Nitroso-N-ethylurea	x						
75-99-0	2,2-Dichloropropionic acid		x					
76-03-9	Trichloroacetic acid		x					
76-06-2	Chloropicrin		x					
76-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane		x					
76-12-0	1,1,2,2-Tetrachloro-1,2-difluoroethane		x					
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane		x					
76-15-3	Chloropentafluoroethane		x					
7616-94-6	Perchloryl fluoride		x					
76-22-2	Camphor, synthetic		x					
7631-90-5	Sodium bisulfite		x					
764-41-0	1,4-Dichloro-2-butene	x						
7646-85-7	Zinc chloride fume		x					
7647-01-0	Hydrogen chloride		x					
765-34-4	Glycidylaldehyde	x						

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
7664-38-2	Phosphoric acid		x					
7664-39-3	Hydrogen fluoride		x					
7664-41-7	Ammonia		x				x	
7664-93-9	Sulfuric acid		x					
76737-07-2	Boron trifluoride		x					
7681-57-4	Sodium metabisulfite		x					
768-52-5	N-Isopropylaniline		x					
7697-37-2	Nitric acid/Nitrate		x				x	x
7719-09-7	Thionyl chloride		x					
7719-12-2	Phosphorus trichloride		x					
7722-84-1	Hydrogen peroxide		x					
7722-88-5	Tetrasodium pyrophosphate		x					
7723-14-0	Phosphorus		x					
7726-95-6	Bromine		x					
7758-97-6	Lead chromate, as Cr		x					
7773-06-0	Ammonium sulfamate		x					
77-73-6	Dicyclopentadiene		x					
77-78-1	Dimethyl sulfate	x						
7782-41-4	Fluorine		x					
7782-49-2C	Selenium compounds, as Se		x					
7782-50-5	Chlorine		x					
7782-65-2	Germanium tetrahydride		x					
7783-06-4	Hydrogen sulfide		x					
7783-07-5	Hydrogen selenide, as Se		x					
7783-41-7	Oxygen difluoride		x					
7783-54-2	Nitrogen trifluoride		x					
7783-60-0	Sulfur tetrafluoride		x					
7783-79-1	Selenium hexafluoride, as Se		x					
7783-80-4	Tellurium hexafluoride, as Te		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/SST	UTS	DST WSPS	Flammable Gases
7784-42-1	Arsine		x					
7786-34-7	Mevinphos		x					
7789-30-2	Bromine pentafluoride		x					
7790-91-2	Chlorine trifluoride		x					
78-00-2	Tetraethyl lead		x					
7803-51-2	Phosphine		x					
7803-52-3	Stibine		x					
7803-62-5	Silicon tetrahydride		x					
78-10-4	Ethyl silicate		x					
78-30-8	Triorthocresyl phosphate		x					
78-34-2	Dioxathion		x					
78-59-1	Isophorone		x					
78-92-2	1-Methylpropyl alcohol		x					
79-04-9	Chloroacetyl chloride		x					
79-09-4	Propanoic acid		x					
79-10-7	2-Propenoic acid		x					
79-11-8	Chloroacetic acid		x					
79-20-9	Methyl acetate		x					
79-24-3	Nitroethane		x					
79-27-6	Acetylene tetrabromide		x					
79-41-4	Methacrylic acid		x					
79-44-7	Dimethylcarbamoyl chloride		x					
79-46-9	2-Nitropropane	x						
794-93-4	Panfuran S (dihydroxymethylfuratrizine)	x						
8001-58-9	Creosote	x						
8002-74-2	Parafin wax fume		x					
8003-34-7	Pyrethrum		x					
8006-64-2	Turpentine		x					
8012-95-1	Oil mist, mineral		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
8022-00-2	Methyl demeton		x					
8030-30-6	Rubber solvent (Naphtha)		x					
8032-32-4	VM & P Naphtha		x					
8052-42-4	Asphalt (petroleum) fumes		x					
8065-48-3	Demeton		x					
81-81-2	Warfarin (>0.3%)		x					
81-81-2a	Warfarin (<0.3%)		x					
822-06-0	Hexamethylene diisocyanate		x					
83-26-1	Pindone		x					
83-79-4	Rotenone		x					
838-88-0	4,4'-Methylenebis(2-methylaniline)	x						
85-00-7	Diquat		x					
86-50-0	Azinphos-methyl		x					
86-88-4	alpha-Naphthylthiourea		x					
88-72-2	Nitrotoluene		x					
88-89-1	Picric acid		x					
89-72-5	o-sec-Butylphenol		x					
90-04-0	o-Anisidine	x						
91-22-5	Quinoline		x					
91-94-1	3,3 -Dichlorobenzidine	x						
92-52-4	1,1`-Biphenyl		x					
92-84-2	Phenothiazine		x					
92-87-5	Benzidine	x						
92-93-3	4-Nitrobiphenyl		x					
94-36-0	Benzoyl Peroxide		x					
944-22-9	Fonofos		x					
95-13-6	Indene		x					
95-49-8	o-Chlorotoluene		x					
95-53-4	o-Toluidine (2-methylaniline)	x						

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
95-80-7	Toluene-2,4-diamine	x						
96-09-3	Styrene oxide		x					
96-22-0	3-Pentanone		x					
96-33-3	Methyl acrylate		x					
96-45-7	Ethylenethiourea	x						
96-69-5	Bis(3-tert-butyl-4-hydroxy-6-methyl-phenyl) sulfide		x					
97-56-3	o-Aminoazotoluene	x						
97-77-8	Disulfiram		x					
98-00-1	Furfuryl alcohol		x					
98-01-1	Furfural		x					
98-07-7	Benzotrichloride		x					
98-51-1	p-tert-Butyltoluene		x					
98-82-8	Cumene		x					
98-83-9	Methylstyrene		x					
999-61-1	2-Hydroxypropyl acrylate		x					
I127	Pu-239/240						x	
I175	U-235						x	
I176	U-gross						x	
I4	Aluminum smelter polyaromatic hydrocarbon emissions	x						
I51	Cotton dust, raw		x					
NA115	Viscosity						x	
NA117	Ignitability (Flash Point)						x	
NA118	Color						x	
NA12	Organics, separable						x	
NA2	Specific gravity (SPG)						x	
NA20	Welding fumes		x					
NA21	Polyaromatic hydrocarbons (PAH)	x						
NA22	Fine mineral fibers		x					
NA23	Fibrous glass dust		x					

Table A-1 Consolidated List of Compounds Used as Input for Regulatory Data Quality Objective List (850 constituents)

CAS#	Constituent	Source of Regulatory DQO Input						
		Class A TAPs	Class B TAPs	UHC	Part A-DST/ SST	UTS	DST WSPS	Flammable Gases
NA24	Dioxins and furans	x						
NA25	Coke oven emissions	x						
NA28	% solids						x	
NA29	Total organic carbon (TOC)						x	
NA3	% moisture						x	
NA30	Total suspended solids						x	
NA38	Total Alpha (AT)						x	
NA6	pH						x	x
NA7	Energetics						x	
UN6	Isopropyl oils	x						
UN8	Nitrofurans	x						

Notes:
[1] Note this compound does not appear on the RDQO input table B.2 although other RDQO tables list it as a TAP and the RDQO input table only lists 849 input compounds.
[2] CAS No. was corrected to hexavalent chromium from RDQO entry.
[3] Corrected CAS No. from RDQO input table B.2.

Table A-2 Priority Regulated Organic Compounds for Characterization in Support of the Regulatory Data Quality Objectives (125 constituents)

CAS #	Constituent	Higher Toxicity Compounds Identified in RDQO Table B-6
100-00-5	p-Nitrochlorobenzene	x
100-25-4	1,4-Dinitrobenzene	
100-41-4	Ethyl benzene	
100-42-5	Styrene	
10061-01-5	cis-1,3-Dichloropropene	
10061-02-6	trans-1,3-Dichloropropene	
106-35-4	3-Heptanone	
106-42-3	p-Xylene	
106-46-7	1,4-Dichlorobenzene	
106-93-4	Ethylene dibromide	
106-97-8	Butane	
106-99-0	1,3-Butadiene	x
107-02-8	Acrolein	x
107-05-1	3-Chloropropene	x
107-06-2	1,2-Dichloroethane	
107-12-0	Propionitrile	x
107-13-1	Acrylonitrile	x
107-87-9	2-Pentanone	
108-10-1	4-Methyl-2-pentanone	
108-38-3	m-Xylene	
108-87-2	Methylcyclohexane	
108-88-3	Toluene	
108-90-7	Chlorobenzene	
108-94-1	Cyclohexanone	
108-95-2	Phenol	
109-66-0	n-Pentane	
109-99-9	Tetrahydrofuran	
110-12-3	5-Methyl-2-hexanone	
110-43-0	2-Heptanone	
110-54-3	n-Hexane	
110-82-7	Cyclohexane	
110-83-8	Cyclohexene	
110-86-1	Pyridine	
111-65-9	n-Octane	
111-84-2	n-Nonane	
118-74-1	Hexachlorobenzene	
120-82-1	1,2,4-Trichlorobenzene	
121-44-8	Triethylamine	
122-39-4	N,N-Diphenylamine	
123-19-3	4-Heptanone	
123-38-6	n-Propionaldehyde	

Table A-2 Priority Regulated Organic Compounds for Characterization in Support of the Regulatory Data Quality Objectives (125 constituents)

CAS #	Constituent	Higher Toxicity Compounds Identified in RDQO Table B-6
123-86-4	Acetic acid n-butyl ester	
123-91-1	1,4-Dioxan	
126-73-8	Tributyl phosphate	x
126-98-7	2-Methyl-2-propenenitrile	x
127-18-4	1,1,2,2-Tetrachloroethene	
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	
1321-64-8	Pentachloronaphthalene	
1335-87-1	Hexachloronaphthalene	
1335-88-2	Tetrachloronaphthalene	
1336-36-3	Polychlorinated biphenyls (PCBs)	
141-78-6	Acetic acid ethyl ester	
142-82-5	n-Heptane	
144-62-7	Oxalic acid	x
2234-13-1	Octachloronaphthalene	
287-92-3	Cyclopentane	
309-00-2	Aldrin	
319-84-6	alpha-BHC	
319-85-7	beta-BHC	
3825-26-1	Ammonium perfluorooctanoate	
4170-30-3	2-Butenaldehyde	
465-73-6	Isodrin	
50-32-8	Benzo(a)pyrene	
53-70-3	Dibenz[a,h]anthracene	
541-73-1	1,3-Dichlorobenzene	
56-23-5	Carbon tetrachloride	
563-80-4	3-Methyl-2-butanone	
57-14-7	1,1-Dimethylhydrazine	x
58-89-9	gamma-BHC (Lindane)	
591-78-6	2-Hexanone	
60-34-4	Methylhydrazine	x
60-57-1	Dieldrin	
624-83-9	Methyl isocyanate	x
627-13-4	Nitric acid, propyl ester	
62-75-9	N-Nitroso-N,N-dimethylamine	x
64-17-5	Ethyl alcohol	
64-18-6	Formic acid	
64-19-7	Acetic acid	
67-56-1	Methyl alcohol	
67-63-0	2-Propyl alcohol	
67-64-1	2-Propanone (Acetone)	
67-66-3	Chloroform	
684-16-2	Hexafluoroacetone	

Table A-2 Priority Regulated Organic Compounds for Characterization in Support of the Regulatory Data Quality Objectives (125 constituents)

CAS #	Constituent	Higher Toxicity Compounds Identified in RDQO Table B-6
71-23-8	n-Propyl alcohol	
71-36-3	n-Butyl alcohol	
71-43-2	Benzene	
71-55-6	1,1,1-Trichloroethane	
72-20-8	Endrin	
74-83-9	Bromomethane	x
74-87-3	Chloromethane	
75-00-3	Chloroethane	
75-01-4	1-Chloroethene	
75-05-8	Acetonitrile	
75-09-2	Dichloromethane (Methylene Chloride)	
75-15-0	Carbon disulfide	
75-21-8	Ethylene oxide (Oxirane)	x
75-34-3	1,1-Dichloroethane	
75-35-4	1,1-Dichloroethene	
75-43-4	Dichlorofluoromethane	
75-45-6	Chlorodifluoromethane	
75-65-0	2-Methyl-2-propanol	
75-69-4	Trichlorofluoromethane	
75-71-8	Dichlorodifluoromethane	
76-13-1	1,2,2-Trichlorotrifluoroethane	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane	
76-44-8	Heptachlor	
78-87-5	1,2-Dichloropropane	
78-92-2	1-Methylpropyl alcohol	
78-93-3	2-Butanone	
79-00-5	1,1,2-Trichloroethane	
79-01-6	1,1,2-Trichloroethylene	
79-10-7	2-Propenoic acid	x
79-34-5	1,1,2,2-Tetrachloroethane	
8001-35-2	Toxaphene	
82-68-8	Pentachloronitrobenzene (PCNB)	
87-68-3	Hexachlorobutadiene	x
87-86-5	Pentachlorophenol	
88-85-7	2-sec-Butyl-4,6-dinitrophenol; syn Dinoseb	
88-89-1	Picric acid	
92-52-4	1,1`-Biphenyl	x
95-47-6	o-Xylene	
95-50-1	1,2-Dichlorobenzene	
96-22-0	3-Pentanone	
98-86-2	Acetophenone	
98-95-3	Nitrobenzene	x

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
100-21-0	Phthalic acid			x	x
100-25-4	1,4-Dinitrobenzene			x	
100-41-4	Ethyl benzene	x			
100-42-5	Styrene	x			
10061-01-5	cis-1,3-Dichloropropene	x			
10061-02-6	trans-1,3-Dichloropropene	x			
101-55-3	4-Bromophenylphenyl ether			x	x
101-84-8	Diphenyl ether	x	x		
106-35-4	3-Heptanone	x			
106-42-3	p-Xylene	x			
106-46-7	1,4-Dichlorobenzene	x			
106-88-7	1,2-Epoxybutane	x	x		
106-93-4	Ethylene dibromide	x			
106-97-8	Butane	x			
107-06-2	1,2-Dichloroethane	x			
107-18-6	2-Propen-1-ol	x	x		
107-31-3	Formic acid, methyl ester	x	x		
107-66-4	Dibutylphosphate			x	x
107-87-9	2-Pentanone	x			
108-03-2	1-Nitropropane	x	x		
108-05-4	Acetic acid vinyl ester	x	x		
108-10-1	4-Methyl-2-pentanone	x			
108-20-3	Bis(isopropyl) ether	x	x		
108-38-3	m-Xylene	x			
108-39-4	m-Cresol	x	x		

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
108-87-2	Methylcyclohexane	x			
108-88-3	Toluene	x			
108-90-7	Chlorobenzene	x			
108-93-0	Cyclohexanol	x	x		
108-94-1	Cyclohexanone	x			
108-95-2	Phenol	x			
109-66-0	n-Pentane	x			
109-99-9	Tetrahydrofuran	x			
110-12-3	5-Methyl-2-hexanone	x			
110-43-0	2-Heptanone	x			
110-54-3	n-Hexane	x			
110-62-3	n-Valeraldehyde	x	x		
110-82-7	Cyclohexane	x			
110-83-8	Cyclohexene	x			
110-86-1	Pyridine	x			
111-65-9	n-Octane	x			
111-76-2	2-Butoxyethanol	x	x		
111-84-2	n-Nonane	x			
117-81-7	Bis(2-ethylhexyl) phthalate	x	x		
117-84-0	Di-n-octylphthalate	x	x		
118-74-1	Hexachlorobenzene			x	
120-12-7	Anthracene			x	x
120-82-1	1,2,4-Trichlorobenzene	x			
120-83-2	2,4-Dichlorophenol			x	x
121-44-8	Triethylamine			x	

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
121-69-7	Dimethylaniline			x	x
122-39-4	N,N-Diphenylamine	x			
123-19-3	4-Heptanone	x			
123-38-6	n-Propionaldehyde	x			
123-51-3	3-Methyl-1-butanol	x	x		
123-86-4	Acetic acid n-butyl ester	x			
123-91-1	1,4-Dioxan	x			
127-18-4	1,1,2,2-Tetrachloroethene	x			
127-19-5	N,N-Dimethylacetamide	x	x		
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	x			
129-00-0	Pyrene	x	x		
1321-64-8	Pentachloronaphthalene			x	
1321-65-9	Trichloronaphthalene			x	x
132-64-9	Dibenzofuran			x	x
1335-87-1	Hexachloronaphthalene			x	
1335-88-2	Tetrachloronaphthalene			x	
1336-36-3	Polychlorinated biphenyls (PCBs)			x	
141-78-6	Acetic acid ethyl ester	x			
141-79-7	4-Methyl-3-penten-2-one	x	x		
142-82-5	n-Heptane	x			
156-60-5	1,2-trans-Dichloroethene			x	x
1582-09-8	Trifluralin			x	x
1634-04-4	Methyl tert-butyl ether			x	x
1836-75-5	Nitrofen			x	x
189-55-9	Dibenzo[a,i]pyrene			x	x

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
189-64-0	Dibenzo[a,h]pyrene			x	x
191-24-2	Benzo(g,h,i)perylene			x	x
191-30-0	Dibenzo(a,l)pyrene			x	x
192-65-4	Dibenzo[a,e]pyrene			x	x
193-39-5	Indeno(1,2,3-cd)pyrene			x	x
205-82-3	Benzo[j]fluoranthene			x	x
205-99-2	Benzo(b)fluoranthene			x	x
206-44-0	Fluoranthene	x	x		
207-08-9	Benzo(k)fluoranthene			x	x
208-96-8	Acenaphthylene			x	x
218-01-9	Chrysene			x	x
2234-13-1	Octachloronaphthalene			x	
224-42-0	Dibenz[a,j]acridine			x	x
226-36-8	Dibenz[a,h]acridine			x	x
2385-85-5	Mirex			x	x
25551-13-7	Trimethyl benzene			x	x
26140-60-3	Terphenyls			x	x
27154-33-2	Trichlorofluoroethane			x	x
287-92-3	Cyclopentane	x			
309-00-2	Aldrin			x	
319-84-6	alpha-BHC			x	
319-85-7	beta-BHC			x	
319-86-8	delta-BHC			x	x
3697-24-3	5-Methylchrysene			x	x
3825-26-1	Ammonium perfluorooctanoate			x	

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
4170-30-3	2-Butenaldehyde	x			
465-73-6	Isodrin			x	
50-00-0	Formaldehyde	x	x		
50-29-3	4,4-DDT			x	x
50-32-8	Benzo(a)pyrene			x	
53-70-3	Dibenz[a,h]anthracene			x	
540-59-0	1,2-Dichloroethylene			x	x
540-84-1	2,2,4-Trimethylpentane			x	x
541-73-1	1,3-Dichlorobenzene	x			
56-23-5	Carbon tetrachloride	x			
563-80-4	3-Methyl-2-butanone	x			
56-49-5	3-Methylcholanthrene			x	x
56-55-3	Benzo(a)anthracene			x	x
58-89-9	gamma-BHC (Lindane)			x	
58-90-2	2,3,4,6-Tetrachlorophenol			x	x
591-78-6	2-Hexanone	x			
59-50-7	4-Chloro-3-methylphenol	x	x		
59-89-2	N-Nitrosomorpholine	x	x		
602-87-9	5-Nitroacenaphthene			x	x
60-29-7	Ethyl ether			x	x
603-34-9	Triphenyl amine			x	x
60-35-5	Acetamide	x	x		
60-57-1	Dieldrin			x	
621-64-7	N-Nitroso-di-n-propylamine	x	x		
627-13-4	Nitric acid, propyl ester	x			

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
630-20-6	1,1,1,2-Tetrachloroethane			x	x
64-17-5	Ethyl alcohol	x			
64-18-6	Formic acid	x			
64-19-7	Acetic acid	x			
67-56-1	Methyl alcohol	x			
67-63-0	2-Propyl alcohol	x			
67-64-1	2-Propanone (Acetone)	x			
67-66-3	Chloroform	x			
67-72-1	Hexachloroethane	x	x		
684-16-2	Hexafluoroacetone			x	
71-23-8	n-Propyl alcohol	x			
71-36-3	n-Butyl alcohol	x			
71-43-2	Benzene	x			
71-55-6	1,1,1-Trichloroethane	x			
72-20-8	Endrin			x	
72-43-5	Methoxychlor			x	x
72-54-8	4,4-DDD			x	x
72-55-9	4,4-DDE			x	x
74-87-3	Chloromethane	x			
74-97-5	Bromochloromethane			x	x
74-99-7	Methylacetylene	x	x		
75-00-3	Chloroethane	x			
75-01-4	1-Chloroethene	x			
75-05-8	Acetonitrile	x			
75-07-0	Acetaldehyde	x	x		

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
75-09-2	Dichloromethane (Methylene Chloride)	x			
75-12-7	Formamide	x	x		
75-15-0	Carbon disulfide	x			
75-27-4	Bromodichloromethane			x	x
75-34-3	1,1-Dichloroethane	x			
75-35-4	1,1-Dichloroethene	x			
75-43-4	Dichlorofluoromethane	x			
75-45-6	Chlorodifluoromethane	x			
75-50-3	Trimethylamine	x	x		
75-52-5	Nitromethane	x	x		
75-55-8	2-Methylaziridine	x	x		
75-61-6	Difluorodibromomethane			x	x
75-63-8	Trifluorobromomethane			x	x
75-65-0	2-Methyl-2-propanol	x			
75-69-4	Trichlorofluoromethane	x			
75-71-8	Dichlorodifluoromethane	x			
75-99-0	2,2-Dichloropropionic acid			x	x
76-03-9	Trichloroacetic acid			x	x
76-11-9	1,1,1,2-Tetrachloro-2,2-difluoroethane			x	x
76-12-0	1,1,2,2-Tetrachloro-1,2-difluoroethane			x	x
76-13-1	1,2,2-Trichlorotrifluoroethane	x			
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane	x			
76-15-3	Chloropentafluoroethane			x	x
76-44-8	Heptachlor			x	
78-83-1	2-Methylpropyl alcohol	x	x		

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
78-87-5	1,2-Dichloropropane	x			
78-92-2	1-Methylpropyl alcohol	x			
78-93-3	2-Butanone	x			
79-00-5	1,1,2-Trichloroethane	x			
79-01-6	1,1,2-Trichloroethylene	x			
79-09-4	Propanoic acid	x	x		
79-20-9	Methyl acetate	x	x		
79-34-5	1,1,2,2-Tetrachloroethane	x			
8001-35-2	Toxaphene			x	
82-68-8	Pentachloronitrobenzene (PCNB)			x	
83-32-9	Acenaphthene	x	x		
84-66-2	Diethyl phthalate	x	x		
84-74-2	Di-n-butylphthalate	x	x		
85-01-8	Phenanthrene			x	x
85-68-7	Butylbenzylphthalate	x	x		
86-73-7	Fluorene	x	x		
87-86-5	Pentachlorophenol			x	
88-06-2	2,4,6-Trichlorophenol	x	x		
88-72-2	Nitrotoluene			x	x
88-75-5	2-Nitrophenol	x	x		
88-85-7	2-sec-Butyl-4,6-dinitrophenol; syn Dinoseb			x	
88-89-1	Picric acid			x	
91-20-3	Naphthalene	x	x		
91-22-5	Quinoline			x	x
91-58-7	2-Chloronaphthalene			x	x

Table A-3 Detected and Non-detected Lower Toxicity Organic Compounds Evaluated in the Regulatory Data Quality Objective Process (217 constituents)

CAS #	Constituent	Detected Lower Toxicity Compounds (RDQO Table B-7)	Detected Lower Toxicity Compounds Removed in the RDOQ Process[1]	Non-detected Lower Toxicity Compounds (RDQO Table B-22)	Non-detected Lower Toxicity Compounds Removed in the RDOQ Process[1]
92-93-3	4-Nitrobiphenyl			x	x
93-72-1	Silvex (2,4,5-TP)			x	x
93-76-5	2,4,5-T			x	x
94-75-7	2,4-D			x	x
95-13-6	Indene			x	x
95-47-6	o-Xylene	x			
95-48-7	o-Cresol	x	x		
95-49-8	o-Chlorotoluene			x	x
95-50-1	1,2-Dichlorobenzene	x			
95-57-8	2-Chlorophenol	x	x		
95-95-4	2,4,5-Trichlorophenol	x	x		
96-22-0	3-Pentanone	x			
96-69-5	Bis(3-tert-butyl-4-hydroxy-6-methyl-phenyl) sulfide	x	x		
98-51-1	p-tert-Butyltoluene			x	x
98-82-8	Cumene			x	x
98-83-9	Methylstyrene	x	x		
98-86-2	Acetophenone	x			

Notes:
[1] These compounds were added back to the WTP COPC list at the request of Ecology and EPA.

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
100-25-4	1,4-Dinitrobenzene	1		x		
100-41-4	Ethyl benzene	1	x	x		x
10061-01-5	cis-1,3-Dichloropropylene	1		x		
10061-02-6	trans-1,3-Dichloropropylene	1		x	x	x
106-42-3	p-Xylene	1	x			
106-46-7	p-Dichlorobenzene	1		x		x
106-93-4	1,2-Dibromoethane/Ethylene dibromide	1		x		
107-02-8	Acrolein	1		x		
107-05-1	3-Chloropropylene	1		x		
107-06-2	1,2-Dichloroethane	1	x	x		x
107-12-0	Ethyl cyanide/ Propanenitrile	1		x		
107-13-1	Acrylonitrile	1		x		
108-10-1	Methyl isobutyl ketone	1	x	x	x	x
108-38-3	m-Xylene	1	x			
108-88-3	Toluene	1	x	x	x	x
108-90-7	Chlorobenzene	1	x	x		x
108-94-1	Cyclohexanone	1	x	x		x
108-95-2	Phenol	1		x		x
110-86-1	Pyridine	1	x	x	x	x
118-74-1	Hexachlorobenzene	1		x		
120-82-1	1,2,4-Trichlorobenzene	1		x		x
121-44-8	Triethylamine	1		x		
122-39-4	Diphenylamine	1		x		
123-91-1	1,4-Dioxane	1		x		
126-98-7	Methacrylonitrile	1		x		
127-18-4	Tetrachloroethylene	1	x	x	x	x
1336-36-3	Total PCBs (sum of Aroclors)	1		x		x
141-78-6	Ethyl acetate	1	x	x		x
309-00-2	Aldrin	1		x		
319-84-6	alpha-BHC	1		x		
319-85-7	beta-BHC	1		x		
465-73-6	Isodrin	1		x		
50-32-8	Benzo(a)pyrene	1		x		
53-70-3	Dibenz(a,h)anthracene	1		x		
541-73-1	m-Dichlorobenzene	1		x		
56-23-5	Carbon tetrachloride	1	x	x	x	x
58-89-9	gamma-BHC	1		x		
60-57-1	Dieldrin	1		x		
62-75-9	N-Nitrosodimethylamine	1		x		
67-56-1	Methanol	1	x	x		
67-64-1	Acetone	1	x	x	x	x
67-66-3	Chloroform	1	x	x	x	x

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
71-36-3	n-Butyl alcohol	1	x	x	x	x
71-43-2	Benzene	1	x	x	x	x
71-55-6	1,1,1-Trichloroethane	1	x	x	x	x
72-20-8	Endrin	1		x		
74-83-9	Bromomethane/Methyl bromide	1		x		
74-87-3	Chloromethane/ Methyl chloride	1		x	x	
75-00-3	Chloroethane	1		x		
75-01-4	Vinyl chloride	1	x	x		x
75-05-8	Acetonitrile	1		x		
75-09-2	Methylene chloride	1	x	x	x	x
75-15-0	Carbon disulfide	1	x	x		x
75-21-8	Ethylene oxide	1		x		
75-34-3	1,1-Dichloroethane	1		x		
75-35-4	1,1-Dichloroethylene	1	x	x	x	x
75-69-4	Trichlorofluorome thane	1	x	x		x
75-71-8	Dichlorodifluoromethane	1		x		
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	1	x	x		x
76-44-8	Heptachlor	1		x		
78-87-5	1,2-Dichloropropane	1		x		
78-93-3	Methyl ethyl ketone	1	x	x	x	x
79-00-5	1,1,2-Trichloroethane	1	x	x	x	x
79-01-6	Trichloroethylene	1	x	x	x	x
79-34-5	1,1,2,2-Tetrachloroethane	1		x		x
8001-35-2	Toxaphene	1		x		
82-68-8	Pentachloronitrobenzene	1		x		
87-68-3	Hexachlorobutadiene	1	x	x		x
87-86-5	Pentachlorophenol	1		x		x
88-85-7	2-sec-Butyl-4,6-dinitrophenol/Dinoseb	1		x		
95-47-6	o-Xylene	1	x			x
95-50-1	o-Dichlorobenzene	1	x	x		x
98-86-2	Acetophenone	1		x		
98-95-3	Nitrobenzene	1	x	x		x
100-21-0	Phthalic acid	2		x		
101-55-3	4-Bromophenylphenyl ether	2		x		
108-39-4	m-Cresol	2	x	x		x
117-84-0	Di-n-octyl phthalate	2		x		x
120-12-7	Anthracene	2		x		
120-83-2	2,4-Dichlorophenol	2		x		
129-00-0	Pyrene	2		x		x
156-60-5	trans-1,2-Dichloroethylene	2		x		
191-24-2	Benzo(g,h,i)perylene	2		x		
192-65-4	Dibenz(a,e)pyrene	2		x		
193-39-5	Indeno(1,2,3-c,d)pyrene	2		x		

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disposition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
205-99-2	Benzo(b)fluoranthene	2		x		
206-44-0	Fluoranthene	2		x		x
207-08-9	Benzo(k)fluoranthene	2		x		
208-96-8	Acenaphthylene	2		x		
218-01-9	Chrysene	2		x		
27154-33-2	Trichlorofluoroethane	2	x			
319-86-8	delta-BHC	2		x		
50-29-3	p,p'-DDT	2		x		
56-49-5	3-Methylcholanthrene	2		x		
56-55-3	Benz(a)anthracene	2		x		
58-90-2	2,3,4,6-Tetrachlorophenol	2		x		
59-50-7	p-Chloro-m-cresol	2		x		x
59-89-2	N-Nitrosomorpholine	2		x		x
60-29-7	Ethyl ether	2	x	x		x
621-64-7	Di-n-propylnitrosamine	2		x		x
630-20-6	1,1,1,2-Tetrachloroethane	2		x		
67-72-1	Hexachloroethane	2	x	x		x
72-43-5	Methoxychlor	2		x		
72-54-8	p,p'-DDD	2		x		
72-55-9	p,p'-DDE	2		x		
75-27-4	Bromodichloromethane	2		x		
78-83-1	Isobutyl alcohol	2	x	x		x
83-32-9	Acenaphthene	2		x		x
84-66-2	Diethyl phthalate	2		x		
84-74-2	Di-n-butylphthalate	2		x	x	x
85-01-8	Phenanthrene	2		x		
85-68-7	Butyl benzyl phthalate	2		x		x
86-73-7	Fluorene	2		x		
88-06-2	2,4,6-Trichlorophenol	2		x		x
88-75-5	o-Nitrophenol	2		x		x
91-20-3	Naphthalene	2		x		x
91-58-7	2-Chloronaphthalene	2		x		
93-72-1	Silvex/2,4,5-TP	2		x		
93-76-5	2,4,5-Trichlorophenoxy acetic acid/ 2,4,5-T	2		x		
94-75-7	2,4-Dichlorophenoxyacetic acid/2,4-D	2		x		
95-48-7	o-Cresol	2	x	x		x
95-57-8	2-Chloropchenol	2		x		x
95-95-4	2,4,5-Trichlorophenol	2	x	x		x
100-02-7	p-Nitrophenol	3		x		x
110-80-5	2-Ethoxyethanol	3	x			x
121-14-2	2,4-Dinitrotoluene	3	x	x		x
1330-20-7	Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations)	3	x	x	x	x

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
79-46-9	2-Nitropropane	3	x			x
576-26-1	Cresylic acid	4	x			
1319-77-3	Cresol (mixed isomers)	5	x			x
100-01-6	p-Nitroaniline	6		x		
100-75-4	N-Nitrosopiperidine	6		x		
101-14-4	4,4-Methylene bis(2-chloroaniline)	6		x		
101-27-9	Barban	6		x		
1024-57-3	Heptachlor epoxide	6		x		
1031-07-8	Endosulfan sulfate	6		x		
105-67-9	2,4-Dimethylphenol	6		x		
10595-95-6	N-Nitrosomethylethylamine	6		x		
10605-21-7	Carbenzadim	6		x		
106-44-5	p-Cresol	6		x		
106-47-8	p-Chloroaniline	6		x		
108-45-2	1,3-Phenylenediamine	6		x		
110-75-8	2-Chloroethyl vinyl ether	6		x		
111-44-4	bis(2-Chloroethyl)ether	6		x		
1114-71-2	Pebulate	6		x		
111-91-1	bis(2-Chloroethoxy)methane	6		x		
1129-41-5	Metolcarb	6		x		
114-26-1	Propoxur	6		x		
120-58-1	Isosafrole	6		x		
120-71-8	p-Cresidine	6		x		
122-42-9	Propham	6		x		
122-66-7	1,2-Diphenylhydrazine	6		x		
124-48-1	Chlorodibromomethane	6		x		
126-72-7	tris-(2,3-Dibromopropyl)phosphate	6		x		
126-99-8	2-Chloro-1,3-butadiene	6		x		
131-11-3	Dimethylphthalate	6		x		
140-57-8	Aramite	6		x		
143-50-0	Kepone	6		x		
1563-38-8	Carbofuran phenol	6		x		
1563-66-2	Carbofuran	6		x		
1646-88-4	Aldicarb sulfone	6		x		
16752-77-5	Methomyl	6		x		
17804-35-2	Benomyl	6		x		
1929-77-7	Vernolate	6		x		
2008-41-5	Butylate	6		x		
2032-65-7	Methiocarb	6		x		
2212-67-1	Molinate	6		x		
22781-23-3	Bendiocarb	6		x		
2303-17-5	Triallate	6		x		

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
23135-22-0	Oxamyl	6		x		
23422-53-9	Formetanate hydrochloride	6		x		
23564-05-8	Thiophanate-methyl	6		x		
23950-58-5	Pronamide	6		x		
2631-37-0	Promecarb	6		x		
298-00-0	Methyl parathion	6		x		
298-02-2	Phorate	6		x		
298-04-4	Disulfoton	6		x		
315-18-4	Mexacarbate	6		x		
3268-87-9	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin (OCDD)	6		x		
33213-65-9	Endosulfan II	6		x		
3424-82-6	o,p'-DDE	6		x		
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	6		x		
39001-02-0	1,2,3,4,6,7,8,9-Octachlorodibenzofluran (OCDF)	6		x		
39638-32-9	bis(2-Chloroisopropyl)ether	6		x		
510-15-6	Chlorobenzilate	6		x		
51-28-5	2,4-Dinitrophenol	6		x		
52-85-7	Famphur	6		x		
52888-80-9	Prosulfocarb	6		x		
53-19-0	o,p'-DDD	6		x		
534-52-1	4,6-Dinitro-o-cresol	6		x		
53-96-3	2-Acetylaminofluorene	6		x		
55-18-5	N-Nitrosodiethylamine	6		x		
55285-14-8	Carbosulfan	6		x		
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofluran	6		x		
56-38-2	Parathion	6		x		
57-47-6	Physostigmine	6		x		
57-64-7	Physostigmine salicylate	6		x		
57-74-9	Chlordane (alpha and gamma isomers)	6		x		
59669-26-0	Thiodicarb	6		x		
60-11-7	p-Dimethylaminoazobenzene	6		x		
606-20-2	2,6-Dinitrotoluene	6		x		
608-93-5	Pentachlorobenzene	6		x		
62-44-2	Phenacetin	6		x		
62-53-3	Aniline	6		x		
63-25-2	Carbaryl	6		x		
64-00-6	m-Cumenylmethylcarbamate	6		x		
66-27-3	Methyl methanesulfonate	6		x		
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofluran	6		x		
7421-93-4	Endrin aldehyde	6		x		
74-88-4	Iodomethane	6		x		
74-95-3	Dibromomethane	6		x		
75-25-2	Tribromomethane/Bromoform	6		x		

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
759-94-4	EPTC	6		x		
76-01-7	Pentachloroethane	6		x		
77-47-4	Hexachlorocyclopentadiene	6		x		
789-02-6	o,p'-DDT	6		x		
79-06-1	Acrylamide	6		x		
80-62-6	Methyl methacrylate	6		x		
85-44-9	Phthalic anhydride	6		x		
86-30-6	N-Nitrosodiphenylamine	6		x		
87-65-0	2,6-Dichlorophenol	6		x		
88-74-4	o-Nitroaniline	6		x		
90-04-0	o-Anisidine (2-methoxyaniline)	6		x		
91-59-8	2-Naphthylamine	6		x		
91-80-5	Methapyrilene	6		x		
924-16-3	N-Nitroso-di-n-butylamine	6		x		
92-67-1	4-Aminobiphenyl	6		x		
930-55-2	N-Nitrosopyrrolidine	6		x		
94-59-7	Safrole	6		x		
95-68-1	2,4-Dimethylaniline (2,4-xylidine)	6		x		
95-94-3	1,2,4,5-Tetrachlorobenzene	6		x		
959-98-8	Endosulfan I	6		x		
96-12-8	1,2-Dibromo-3-chloropropane	6		x		
96-18-4	1,2,3-Trichloropropane	6		x		
97-63-2	Ethyl methacrylate	6		x		
98-87-3	Benzal chloride	6		x		
99-55-8	5-Nitro-o-toluidine	6		x		
NA	Dithiocarbamates (total)	6		x		
NA1	Chlorinated fluorocarbons, N.O.S.	6	x			
126-73-8	Tributyl phosphate	7			x	x
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	7				x
591-78-6	2-Hexanone	7			x	
108-05-4	Vinyl acetate	8			x	
111-76-2	Ethylene glycol monobutyl ether	8			x	
117-81-7	Bis(2-ethylhexyl)phthalate	8			x	
100-42-5	Styrene	9				
107-87-9	2-Pentanone	9				
109-99-9	Tetrahydrofuran	9				
111-84-2	n-Nonane	9				
132-64-9	Dibenzofuran	10				
540-59-0	1,2-Dichloroethylene	10				
98-82-8	Cumene	10				
12311-97-6	Formate	11			x	x
126-44-3	Citrate	11			x	
150-39-0	HEDTA (Hydroxyethylethylenediaminetriacetic acid)	11			x	

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
338-70-5	Oxalate	11			x	
60-00-4	EDTA (Ethylenediaminetetraacetic acid)	11			x	
666-14-8	Glycolate	11			x	x
71-50-1	Acetate	11			x	x
1024-57-D	Heptachlor epoxide isomers	12				
108-60-1	Bis(2-Chloroisopropyl) ether	12				
11141-16-5	Aroclor 1232	12				
1134-23-2	Cycloate	12				
119-38-0	Isolan	12				
12672-29-6	Aroclor 1248	12				
135-88-6	N-Phenyl-2-napthylamine	12				
137-30-4	Ziram	12				
17702-57-7	Formparanate	12				
1888-71-7	Hexachloropropylene	12				
22961-82-6	Bendiocarb phenol	12				
26419-73-8	Tirpate	12				
30558-43-1	Oxamyl-oxime (A2213)	12				
55406-53-6	3-Iodo-2-propynyl n-butylcarbamate	12				
57-74-D	Chlordane (alpha and gamma isomers)	12				
5952-26-1	Diethylene glycol, dicarbamate	12				
644-64-4	Dimetilan	12				
95-54-5	1,2-Phenylenediamine	12				
HxCDD	HxCDDs (All Hexachlorodibenzo-p-dioxins)	12				
HxCDF	HxCDFs (All Hexachlorodibenzofurans)	12				
PeCDD	PeCDDs (All Pentachlorodibenzo-p-dioxins)	12				
PeCDF	PeCDFs (All Pentachlorodibenzofurans)	12				
TCDD	TCDDs (All Tetrachlorodibenzo-p-dioxins)	12				
TCDF	TCDFs (All Tetrachlorodiben zofurans)	12				
16984-48-8	Fluoride	13		x		
18496-25-8	Sulfide	13		x		
57-12-5	Cyanides (Total)	13		x		
57-12-5a	Cyanides (Amenable)	13		x		
7439-92-1	Lead	13	x	x		
7439-97-6	Mercury--All Others	13	x	x		
7439-97-6r	Mercury--Nonwaste water from Retort	13		x		
7440-02-0	Nickel	13		x		
7440-22-4	Silver	13	x	x		
7440-28-0	Thallium	13		x		
7440-36-0	Antimony	13		x		
7440-38-2	Arsenic	13	x	x		
7440-39-3	Barium	13	x	x		
7440-41-7	Beryllium	13		x		
7440-43-9	Cadmium	13	x	x		

Table A-4 Updates to the Organic RDQO Input List (302 constituents)

CAS #	Constituent	Disp-osition [a]	DST Part A Update [b]	UHC / UTS Update [c]	TWINS [d]	BBI [e]
7440-47-3	Chromium (Total)	13	x	x		
7440-62-2	Vanadium	13		x		
7440-66-6	Zinc	13		x		
7782-49-2	Selenium	13	x	x		

Disposition [a]

1 RDQO starting list compounds retained in the evaluation of the UHC/UTS/DST Part A updates; no changes to the previous COPC list (74 constituents).
2 Low-toxicity compounds retained in the evaluation of the UHC/UTS/DST Part A updates; no changes to the previous COPC list (49 constituents).
3 Constituents eliminated in the RDQO process; the review of the UHC/UTS/DST Part A updates and comparison with TWINS/BBI added them to the feed COPC list (5 constituents).
4 Compound added as a result of DST Part A updates; not found in TWINS or BBI; removed because it's not stable in tank waste (1 constituent).
5 No methods available for tank waste matrices; removed in favor of m, o, and p isomers that will be analyzed per existing methods (1 constituent).
6 Compounds that are listed in the UHC/UTS updates; not found in TWINS or BBI and eliminated (109 constituents).
7 RDQO starting list compounds removed from UHC/UTS/DST Part A lists by updates; retained because they are found in TWINS/BBI (3 constituents).
8 Low-toxicity compounds removed from UHC/UTS/DST Part A lists by updates; retained because they are found in TWINS/BBI (3 constituents).
9 RDQO starting list compounds removed from UHC/UTS/DST Part A lists by updates; eliminated (4 constituents).
10 Low-toxicity compounds removed from UHC/UTS/DST Part A lists by updates; eliminated (3 constituents).
11 Compounds found in TWINS or BBI; do not appear on UHC/UTS, or DST Part A lists; eliminated (7 constituents).
12 Compounds originally input to the RDQO solely because they appear on UHC/UTS, or DST Part A lists; removed in the UTS/UHD/DST Part A updates; not in TWINS/BBI; eliminated (24 constituents).
13 Inorganic compounds that were not further evaluated (19 constituents).

[b] Compounds identified by the updates to the DST Part A; identified with an "x".
[c] Compounds identified by updates to the UTS/UHC lists in 40 CFR 268; identified with an "x".
[d] Compounds with 10 or more detects in TWINS; identified with an "x".
[e] Compounds listed in BBI; identified with an "x".

Note: those compounds appearing on the TAPs Update lists (Appendix C) will be further evaluated.

Table A-5 Inorganic Constituents Identified in the RDQO Process (52 constituents)

CAS #	Cation	Constituent
18540-29-9	Cr	Chromium(VI)
63705-05-5	S	Total Sulfur
7429-90-5	Al	Aluminum
7439-89-6	Fe	Iron
7439-92-1	Pb	Lead
7439-93-2	Li	Lithium
7439-95-4	Mg	Magnesium
7439-96-5	Mn	Manganese
7439-97-6	Hg	Mercury
7439-98-7	Mo	Molybdenum
7440-02-0	Ni	Nickel
7440-06-4 [a]	Pt	Platinum
7440-09-7	K	Potassium
7440-16-6	Rh	Rhodium
7440-21-3	Si	Silicon
7440-22-4	Ag	Silver
7440-23-5	Na	Sodium
7440-25-7	Ta	Tantalum
7440-28-0	Tl	Thallium
7440-31-5	Sn	Tin
7440-33-7	W	Tungsten
7440-36-0	Sb	Antimony
7440-38-2	As	Arsenic
7440-39-3	Ba	Barium
7440-41-7	Be	Beryllium
7440-42-8	B	Boron
7440-43-9	Cd	Cadmium
7440-46-2 [a]	Cs	Cesium
7440-48-4	Co	Cobalt
7440-50-8	Cu	Copper
7440-61-1	U	Uranium
7440-62-2	V	Vanadium
7440-65-5	Y	Yttrium
7440-66-6	Zn	Zinc
7440-67-7	Zr	Zirconium
7440-69-9	Bi	Bismuth
7440-70-2	Ca	Calcium
7664-41-7	NH_4/NH_3	Ammonia/Ammonium
7723-14-0	P	Phosphorus
7782-49-2	Se	Selenium
Total Cations: 40		

Table A-5 Inorganic Constituents Identified in the RDQO Process (52 constituents)

CAS#	Anion	Constituent
24959-67-9	Br	Bromide
16887-00-6	Cl	Chloride
57-12-5	CN	Cyanide
16984-48-8	F	Fluoride
7553-56-2	I	Iodine
14797-65-0	NO_2	Nitrite
7697-37-2	NO_3	Nitrate
14280-30-9	OH	Hydroxide
14265-44-2	PO_4	Phosphate
18496-25-8 [a]	S	Sulfides
14265-45-3 [a]	SO_3	Sulfite
14808-79-8	SO_4	Sulfate
Total Anions: 12		

[a] Analysis not requested by RDQO (Wiemers and others 1998).

Appendix B

Hanford Tank System Industrial Hygiene Chemical Vapor Technical Basis

Appendix B
Hanford Tank System Industrial Hygiene Chemical Vapor Technical Basis

The purpose of the *Industrial Hygiene Chemical Vapor Technical Basis* produced by CH2M HILL Hanford Group (CHG 2004) report was to update and consolidate technical information related to the industrial hygiene program at the tank waste storage system. The approach was based on an assessment of the current knowledge regarding the gases and vapors released by the liquid waste or generated by the ongoing decomposition of tank wastes.

The assessment process started with a list of 1,826 chemicals; then, toxicological data were collected. The chemicals of potential concern (COPC) were developed by applying the following criteria:

- Chemical is a carcinogen.
- Chemical was identified by tank headspace sampling and analysis.
- Chemical could plausibly exist in the tank waste or headspace.

This process identified 52 compounds as constituents of potential concern (CH2M HILL 2004, Chapter 5, Tables 5-5 and 5-6). Table B-1 of this appendix lists the COPCs that resulted from the process. Seventeen compounds were not previously identified as potential WTP waste feed constituents from the RDQO process. Thirteen of these compounds were added to the WTP waste feed COPC list, three were added to the WTP stack emissions list, and one, nitrous oxide (CAS No. 10024-97-2) was removed and managed as described in Appendix D.

Two vapor study COPCs, aroclors 1242 and 1254 were identified during the RDQO Optimization, and later removed in favor of total PCB analysis (Appendix G). Further modifications and evaluations added three compounds to the list of CHG-identified COPCs; see Appendix C and Appendix G.

Reference:

CHG 2004. JO Honeyman, JE Meacham, RJ Cash, AM Sastry. CH2M HILL Hanford Group, Inc. JL Huckaby, Pacific Northwest National Laboratory, *Industrial Hygiene Chemical Vapor Technical Basis*, RPP-22491, October 2004, Richland, Washington.

Table B-1 Compounds Identified in the Hanford Tank System Chemical Vapor Industrial Technical Basis (52 constituents)

CAS #	Constituent	Additions to the WTP COPC List [1]
106-93-4	Ethylene dibromide	
106-99-0	1,3-Butadiene	
107-06-2	1,2-Dichloroethane	
107-12-0	Propionitrile	
123-91-1	1,4-Dioxan	
126-73-8	Tributyl phosphate	
127-18-4	1,1,2,2-Tetrachloroethene	
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	
56-23-5	Carbon tetrachloride	
57-14-7	1,1-Dimethylhydrazine	
591-78-6	2-Hexanone	
60-34-4	Methylhydrazine	
624-83-9	Methyl isocyanate	
62-75-9	N-Nitroso-N,N-dimethylamine	
67-56-1	Methyl alcohol	
67-66-3	Chloroform	
71-36-3	n-Butyl alcohol	
71-43-2	Benzene	
75-01-4	1-Chloroethene (vinyl chloride)	
75-05-8	Acetonitrile	
75-09-2	Dichloromethane (Methylene chloride)	
75-15-0	Carbon disulfide	
75-21-8	Ethylene oxide (Oxirane)	
79-01-6	1,1,2-Trichloroethylene	
79-10-7	2-Propenoic acid	
92-52-4	1,1`-Biphenyl	
117-81-7	bis (2-Ethylhexyl) phthalate	
50-00-0	Formaldehyde	
72-55-9	4,4-DDE	
75-07-0	Acetaldehyde	
75-50-3	Trimethylamine	
84-66-2	Diethyl phthalate	
79-46-9	2-Nitropropane	
10595-95-6	n-Nitrosomethylethylamine	x
100-40-3	4-Ethenylcyclohexene	x
104-76-7	2-Ethyl-1-hexanol	x
109-74-0	n-Butanenitrile	x
110-59-8	Pentanenitrile	x
123-72-8	Butanal	x

Table B-1 Compounds Identified in the Hanford Tank System Chemical Vapor Industrial Technical Basis (52 constituents)

CAS #	Constituent	Additions to the WTP COPC List [1]
134-32-7	alpha-Naphthylamine	x
589-38-8	3-Hexanone	x
628-73-9	Hexanenitrile	x
75-02-5	Fluoroethene (vinyl fluoride)	x
593-74-8	Dimethyl Mercury	x
10102-44-0	Nitrogen dioxide [2]	x
124-38-9	Carbon dioxide [2]	x
630-08-0	Carbon monoxide [2]	x
10024-97-2	Nitrous oxide [3]	x
11097-69-1	Aroclor-1254 [4]	x
53469-21-9	Aroclor-1242 [4]	x
7439-97-6	Mercury	
7664-41-7	Ammonia	

[1] Compounds listed in the CHG vapor study report that are retained as WTP COPCs; identified by an "x".
[2] Stack emission compound.
[3] Removed; see Appendix D.
[4] Removed by agreement with Ecology and EPA, see Appendix G.

Appendix C

Update to Toxic Air Pollutant List WAC 173-460

Appendix C
Update to Toxic Air Pollutant List WAC 173-460

In June 2009, Ecology updated the list of toxic air pollutants (TAP) by issuing a revision to WAC 173-460. The updated TAPs list consists of 395 compounds and compound classes (Table C-1). In order to determine whether changes were needed to the WTP COPC list, the updated list of TAPs was compared to the following inputs to the WTP COPC list:

- RDQO (Wiemers and others, 1998) inputs including (Appendix A, Section A.1):
  - List of Class A and Class B toxic air pollutants as promulgated in WAC 173-460 prior to the June 2009 update
  - Underlying Hazardous Constituent (UHC) list [40 CFR 268.2(i)]
  - Universal Treatment Standards (UTS) list (40 CFR 268.48)
  - Double Shell Tank RCRA Part A permit application constituents, except waste code F039 (DOE-RL 1996)
  - Double Shell Tank Waste Stream Profile Sheet (WSPS) constituents
- Low-toxicity constituents added as COPCs by agreement with Ecology and EPA (Appendix A)
- Updates to the RDQO input list of UHC, UTS, and DST Part A constituents (Appendix A, Section A.2)
- Constituents added by the CHG Hanford tank industrial hygiene vapor study (CHG 2004) (Appendix B)

When comparing the TAPs updates to the list of COPCs identified in Appendix A and Appendix B, the following rules were applied:

- If the constituent was identified as an RDQO organic feed COPC (Appendix A, Table A-2) and retained in the updated TAPs list, it was retained as a WTP feed COPC without further evaluation.
- If the constituent was identified as a low-toxicity feed COPC (Appendix A, Table A-3) and retained in the updated TAPs list, it was retained as a WTP feed COPC without further evaluation.
- If the constituent was identified as an RDQO or low-toxicity feed COPC (Appendix A, Table A-2 and Table A-3) and retained in the updated UHC/UTS, DST Part A list (Appendix A, Table A-4), it was retained as a WTP feed COPC without further evaluation.
- If the constituent was identified as an RDQO inorganic feed COPC (Appendix A, Table A-5) (ions) and a compound containing the ion appears in the updated TAPs list, it was retained as a WTP feed COPC without further evaluation.
- If the constituent was identified in the CHG vapor study (Appendix B, Table B-1) as a compound of interest, it was retained without further evalaution.

For those constituents identified in the original RDQO input lists (Appendix A, Table A-1) as a TAP, but removed by the update, the constituent was eliminated as a feed COPC if it was not identified in the UHC/UTS/DST Part A (Appendix A, Table A-4) or CHG vapor study lists (Appendix B, Table B-1), and it is not listed in Tank Waste Information Network System (TWINS) database with more than 10 detects (PNNL 2010) or the Best Basis Inventory (BBI) (PNNL 2010) (Appendix A, Table A-4).

Appendix A provides additional details of the RDQO process and Appendix B provides additional information regarding the industrial hygiene study. Sections C.1 and C.2 summarize the disposition of TAPs and identify those COPCs retained as a result of the TWINS and BBI analysis.

C.1 Review of the Updated Toxic Air Pollutant List

The review of the updated TAPs list (Table C-1) (395 compounds) categorized the compounds as follows:

- 209 constituents on the TAPs list were previously evaluated as old TAPs (Class A or B TAPs) input to the RDQO (Table C-1, footnote b)
- 26 were previously evaluated as other inputs to the RDQO [i.e., identified as underlying hazardous constituents (UHCs, 40 CFR 268.2(i)); appear on the universal treatment standards (UTS, 40 CFR 268.48) list, are listed in the Double Shell Tank RCRA Part A permit application (DOE-RL 1991), listed on the Double Shell Tank Waste Stream Profile Sheets (WSPSs)] (Table C-1, footnote c)
- 6 were evaluated with the update to the UHCs/UTS or DST Part A constituent inputs to the RDQO (Table C-1, footnote d, less those constituents marked with footnotes b and c)
- 3 were identified in the CHG vapor study; 1 inorganic compound, dimethyl mercury (CAS #593-74-8), was previously retained as a CHG vapor study COPC and was retained as a feed COPC without further evaluation and 2 (criteria pollutants) will be addressed as stack emissions compounds (Table C-1, footnote e, less those constituents marked with footnotes b, c and d).
- 151 constituents were not previously evaluated as waste feed COPCs.

The evaluation of the 395 constituents listed in the WAC 173-460 revision produced the following (refer to Table C-1 for disposition codes):

- 97 Organics were retained as WTP feed COPCs (59 from the starting list of 125 (disposition 1) (RDQO list of 125 constituents is discussed in Appendix A and shown in Table A-2) and 38 added back as low toxicity compounds (disposition 3).
- 39 Inorganics were addressed as individual ions in the WTP feed as described in the RDQO (disposition 2).
- 3 Organics were added as a result of the UHC/UHC and DST Part A update review (discussed in Appendix A and shown in Table A-4) (disposition 4).
- 1 Organic compound (TAP) was previously identified in the CHG industrial hygiene study (Appendix B) and retained as a WTP feed COPC (disposition 5).
- 3 Inorganic compounds were identified by CHG in the tank vapor space; one (dimethyl mercury) will be measured in feed as total mercury (disposition 6); 2 compounds (nitrogen dioxide and carbon monoxide) are also identified by EPA as criteria pollutants and will be measured in stack emissions (disposition 6).
- 1 Organic compound on the RDQO starting list; the regulatory basis was removed in the UHC/UTS, DST Part A evaluation (Appendix A, Table A-4), but the TAPs update provides the new regulatory basis (disposition 7)

- 1 Organic compound added as low-toxicity compounds; the regulatory basis was removed in the UHC/UTS, DST Part A evaluation (Appendix A, Table A-4), but the TAPs update provides the new regulatory basis (disposition 8).
- 4 Compounds were identified as criteria pollutants to be measured in stack emissions. Note, the CHG vapor study has already identified two of the compounds (nitrogen dioxide and carbon monoxide) as vapor constituents to be measured in stack emissions (see bullet 5). The remaining 2 compounds (sulfur dioxide and ozone) were added to the COPC list (disposition 9).
- 4 inorganic compounds were assigned to the stack emissions COPC list; the compounds were previously assigned to stack emissions measurements by agreement with Ecology (CCN 097844) (disposition 10).
- 29 dioxin, furan, and related compounds that are listed by EPA as potential PICs were identified to be measured in stack emissions (discussed in Appendix E) (disposition 11).
- 3 generic dioxin furan compounds were included on the TAPs update list; these were eliminated because the specific dioxin/furan compounds are COPCs and thus, the generic forms do not need to be carried as COPCs (disposition 12).
- 212 constituents were eliminated as feed constituents, no TWINS or BBI hits exceeding the selection criteria (i.e., $\geq$ 10 instances of analytical detection in TWINS or listed in the BBI); therefore, none of these COPCs were added to the WTP feed list (disposition 13, 14, and 15). No previous additions to the COPC list were removed.
- 39 of the 212 eliminated constituents will be retained as stack emission compounds because they appear on the EPA (Appendix E) and/or site-specific (Appendix F) PIC lists (disposition 13, and 14).

C.2 Review of WTP COPCs Removed as RDQO Inputs by the TAPs Revision

The WAC 173-460, before the June 2009 revision, listed 669 Class A and B TAPs (Table C-2). The WAC 173-460 revision (June 2009) retained 209 compounds from the TAPs Class A and Class B lists and removed 460 TAPs. The 209 TAPs retained in the WAC 173-460 revision were evaluated along with the 186 TAPs additions in the WAC revision and dispositioned as described in Section C.1.

Of the 460 compounds removed by the WAC revision, 50 were originally (Wiemers and others, 1998) input to the RDQO as Class A or B TAPs inputs; however, they also appeared on other lists used as input to the RDQO (i.e., they were dual regulated under another statute or had been identified as waste components). The updates to the UHC/UTS/DST Part A list (Appendix A, Table A-4) removed 8 constituents from dual regulation leaving them solely regulated as former TAPs; the 42 remaining dual regulated compounds were evaluated to determine if COPCs should be added to the WTP feed or stack emission lists.

C.2.1 Compounds Listed as UHC/UTS, DST Part A Inputs to RDQO

The 42 compounds (as adjusted by the UHC/UTS/DST Part A updates Appendix A, Table A-4) previously evaluated by the RDQO (Appendix A) were also listed as UHC [40 CFR 268.2(i)], UTS (40 CFR 268.48), or Double Shell Tank RCRA Part A permit application constituents (Table C-3). See the RDQO (Wiemers and others 1998) for details of the inputs and evaluations. Of these 42 constituents, the RDQO process, the update to the UHC/UTS, DST Part A input lists, and the CHG vapor study identified 28 organic and inorganic compounds as feed COPCs and eliminated 14 as feed COPCs.

The 42 compounds were compared to TWINS and BBI databases to determine if information available after the completion of the RDQO indicated that these compounds are potentially present in tank waste. Three of the 17 eliminated compounds appear as EPA and site-specific PICs lists to be measured in stack emissions (Appendix E and Appendix F). The 42 compounds are dispositioned as follows (see Table C-3 for disposition codes):

- 16 Organics were retained as WTP feed COPCs from the RDQO starting list of 125 (Table C-3, disposition 1)
- 8 Organics were added back as low toxicity compounds (discussed in Appendix A and shown in Table A-4) (Table C-3, disposition 2).
- 1 Organic compound added as a result of evaluation of updates to RDQO inputs (UHC/UTS, DST Part A) (disposition 3)
- 3 Inorganics were addressed as individual ions in the WTP feed as described in the RDQO (disposition 4).
- 14 Organic compounds were eliminated (dispositions 5, 6, 7) because their presence as a UHC was not sufficient justification for retention (these were not DST Part A, WSPS, or flammable gas constituents, and were not found in TWINs or BBI in excess of the retention criteria); note 4 of the eliminated compounds will be measured in stack emissions as EPA (Appendix E) or site-specific PICS (Appendix F)

C.2.2 Compounds Input to RDQO As Old TAPs

Of the 460 TAPs removed from regulation, 418 were identified as no longer being subject to regulatory drivers that would automatically warrant their inclusion as COPCs, 8 of which were no longer UHCs since the latest update to 40 CFR 268.2. The original evaluation of the other 418 Class A and B TAPs by the RDQO[11] resulted in the identification of 85 organic compounds as either feed COPCs (Appendix A, Table A-2) or low toxicity compounds (that were subsequently added back to the COPC list by agreement with Ecology, see Appendix A, Table A-3). All 418 compounds were reviewed for changes to the previous determinations.

Of the 418 constituents, 323 are organics. They were compared to TWINS and BBI databases to determine if data existed to warrant changing their retention or removal status (i.e., ≥ 10 instances of analytical detection in TWINS or listed in the BBI). The 323 constituents were dispositioned as follows (the disposition numbers refer to the number codes in the disposition column in Table C-4):

- 42 feed COPCs from the 418 Class A or Class B TAPs were retained in the RDQO starting list of 125 COPCs (Appendix A, Table A-2); they were dispositioned as follows (see Table C-4 for disposition codes):
    - 3 were retained as feed COPCs because they appear in TWINS or BBI (disposition 1)
    - 2 were retained as feed COPCs because they are identified in the CHG vapor study (disposition 2)
    - 8 were removed as feed COPCs; they were added back as stack emissions compounds because they appear on the EPA (Appendix E) or site-specific Appendix F) PIC list (disposition 3 and 4)
    - 29 were removed because they no longer have a regulatory driver and do not appear in TWINS or BBI (disposition 5)

[11] Metal containing TAP constituents were represented in the RDQO by their associated representative metal in elemental form.

- 43 feed COPCs were added back as low-toxicity compounds (Appendix A, Table A-3); they were dispositioned as follows:
  - 1 was retained because it was identified in the CHG vapor study (disposition 6)
  - 7 were removed as feed COPCs; they were added back as stack emissions compounds because they appear on the EPA (Appendix E) or site-specific Appendix F) PIC list (disposition 7 and 8)
  - 35 were removed because they no longer have a regulatory driver and do not appear in TWINS or BBI (disposition code 9)
- 95 Compounds are inorganic; they were dispositioned as follows:
  - 5 were retained in the RDQO process and not further evaluated (disposition 10)
  - 90 were addressed as individual inorganic ions in the RDQO process and not further evaluated (disposition 11)
- 238 were previously eliminated in the RDQO process and are not low-toxicity constituents; these were dispositioned as follows:
  - 1 was retained as a feed COPC because it appears on the CHG vapor study list (Appendix B, Table B-1) (disposition 12)
  - 13 were added back as EPA PICs (3.3Appendix E) (disposition 13)
  - 224 were eliminated (disposition 14)

C.3 References

40 CFR 60. *Standards of Performance for New Stationary Sources*, Current as of August 1, 2007, US Environmental Protection Agency, Washington, DC.

40 CFR 268. *Land Disposal Restrictions*, US Environmental Protection Agency, Washington, DC.

CHG 2004. *Industrial Hygiene Chemical Vapor Technical Basis*, RPP-22491, Rev 0. CH2M HILL Hanford Group, Inc., Richland, Washington.

DOE-RL. 1991. *Double-Shell Tank (DST) System Dangerous Waste Permit Application*, DOE/RL-90-39, Rev 0, June 1991. US Department of Energy, Richland Operations Office, Richland, Washington.

PNNL 2010. *Tank Waste Information Network System*, accessed October 20, 2010, available at http://twinsweb.pnl.gov/twins.htm, Pacific Northwest National Laboratory, Richland, Washington.

WAC 173-460. *Controls for New Sources of Toxic Air Pollutants*, Washington Administrative Code, Olympia, Washington.

Wiemers KD, Lerchen ME, Miller M, and Meier K. 1998. *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project,* PNNL-12040, Rev 0, December 1998. Pacific Northwest National Laboratory, Richland, Washington.

Table C-1 Updated List of Toxic Air Pollutants (395 constituents)

CAS #	Constituent	Disp-osition [a]	Old TAP Input to RDQO Table A-1 [b]	Other Inputs to RDQO Table A-1 [c]	Updates to RDQO Input List Table A-4 [d]	Compare w/ CHG Vapor Study List Table B-1 [e]	Compare w/ TWINS/BBI List Table A-4 [f]	Compare w/ EPA PICs Table E-1 [g]	Compare w/ Site-Specific PICs Table F-1 [h]
100-41-4	Ethylbenzene	1		x	x		x	x	
106-42-3	p-Xylene	1		x	x			x	
106-46-7	1,4-Dichlorobenzene	1	x		x		x	x	
106-93-4	1,2-Dibromoethane	1	x		x			x	
106-99-0	1,3-Butadiene	1	x					x	
107-02-8	Acrolein	1	x		x			x	
107-05-1	Allyl Chloride	1	x		x				x
107-06-2	1,2-Dichloroethane	1	x		x		x	x	
107-13-1	Acrylonitrile	1	x		x			x	
108-10-1	Methyl Isobutyl Ketone	1	x		x		x	x	
108-38-3	m-Xylene	1		x	x			x	
108-88-3	Toluene	1	x		x		x	x	
108-90-7	Chlorobenzene	1	x		x		x	x	
108-95-2	Phenol	1	x		x		x	x	
110-54-3	n-Hexane	1	x					x	
110-82-7	Cyclohexane	1	x						
118-74-1	Hexachlorobenzene	1	x		x			x	
121-44-8	Triethylamine	1	x		x				
123-91-1	1,4-Dioxane	1	x		x			x	
127-18-4	Perchloroethylene	1	x		x		x	x	
1336-36-3	Polychlorinated Biphenyls, NOS	1	x		x		x		
309-00-2	Aldrin	1	x		x				
319-84-6	alpha-Hexachlorocyclohexane	1	x		x			x	
319-85-7	Beta-hexachlorocyclohexane	1	x		x			x	
50-32-8	Benzo[a]pyrene	1	x		x				x
53-70-3	Dibenz[a,h]anthracene	1	x		x				x
56-23-5	Carbon Tetrachloride	1	x		x		x		x
57-14-7	1,1-Dimethylhydrazine	1	x						

Table C-1 Updated List of Toxic Air Pollutants (395 constituents)

CAS #	Constituent	Disp-osition [a]	Old TAP Input to RDQO Table A-1 [b]	Other Inputs to RDQO Table A-1 [c]	Updates to RDQO Input List Table A-4 [d]	Compare w/ CHG Vapor Study List Table B-1 [e]	Compare w/ TWINS/BBI List Table A-4 [f]	Compare w/ EPA PICs Table E-1 [g]	Compare w/ Site-Specific PICs Table F-1 [h]
58-89-9	gamma-Hexachlorocyclohexane	1	x		x				
60-57-1	Dieldrin	1	x		x				
624-83-9	Methyl Isocyanate	1	x						
62-75-9	n-Nitrosodimethylamine	1	x		x				
67-56-1	Methyl Alcohol	1	x		x				
67-63-0	Isopropyl Alcohol	1	x						
67-66-3	Chloroform	1	x		x		x		x
71-43-2	Benzene	1	x		x		x		x
71-55-6	1,1,1-Trichloroethane	1	x		x		x		
74-83-9	Methyl Bromide	1	x		x				x
74-87-3	Methyl Chloride	1	x		x		x		x
75-00-3	Ethyl Chloride	1	x		x				x
75-01-4	Vinyl Chloride	1	x		x		x		x
75-05-8	Acetonitrile	1	x		x				x
75-09-2	Dichloromethane	1	x		x		x		x
75-15-0	Carbon disulfide	1	x		x		x		x
75-21-8	Ethylene oxide	1	x		x				
75-34-3	1,1-Dichloroethane	1	x		x				x
75-35-4	1,1-Dichloroethylene	1	x		x		x		x
75-45-6	Chlorodifluoromethane	1	x						
76-44-8	Heptachlor	1	x		x				
78-87-5	1,2-Dichloropropane	1	x		x				
78-93-3	Methyl Ethyl Ketone	1	x		x		x		x
79-00-5	1,1,2-Trichloroethane	1	x		x		x		
79-01-6	Trichloroethylene	1	x		x		x		x
79-10-7	Acrylic Acid	1	x						
79-34-5	1,1,2,2-Tetrachloroethane	1	x		x		x		
8001-35-2	Toxaphene	1	x		x				
87-68-3	Hexachlorobutadiene	1	x		x		x		x

Table C-1 Updated List of Toxic Air Pollutants (395 constituents)

CAS #	Constituent	Disp-osition [a]	Old TAP Input to RDQO Table A-1 [b]	Other Inputs to RDQO Table A-1 [c]	Updates to RDQO Input List Table A-4 [d]	Compare w/ CHG Vapor Study List Table B-1 [e]	Compare w/ TWINS/BBI List Table A-4 [f]	Compare w/ EPA PICs Table E-1 [g]	Compare w/ Site-Specific PICs Table F-1 [h]
87-86-5	Pentachlorophenol	1	x		x		x		
95-47-6	o-Xylene	1		x	x		x		
10028-22-5	Ferric Sulfate	2							
10049-04-4	Chlorine dioxide	2	x						
10294-40-3	Barium Chromate	2							
11115-74-5	Chromic Acid	2							
12035-72-2	Nickel Subsulfide	2							
1304-56-9	Beryllium Oxide	2							
1309-64-4	Antimony Trioxide	2	x						
1310-73-2	Sodium Hydroxide	2	x						
1314-62-1	Vanadium Pentoxide	2	x						
1333-82-0	Chromic Trioxide	2							
13510-49-1	Beryllium Sulfate	2							
16984-48-8	Fluoride containing chemicals, NOS	2	x		x				
18454-12-1	Lead Chromate Oxide	2							
18540-29-9	Chromium(VI)	2	x						
18540-29-9C	Chromium Hexavalent: Soluble, except Chromic Trioxide	2							
7439-92-1D	Lead and compounds (NOS)	2	x						
7439-96-5Ca	Manganese & Compounds	2	x						
7439-97-6	Mercury, Elemental	2		x	x				
7440-38-2C	Arsenic & Inorganic Arsenic Compounds	2	x						
7440-41-7N	Beryllium & Compounds (NOS)	2							
7440-43-9	Cadmium & Compounds	2	x		x				
7440-48-4a	Cobalt	2	x						
7440-50-8C	Copper & Compounds	2	x						
7440-62-2	Vanadium	2		x	x				
7550-45-0	Titanium Tetrachloride	2	x						
7664-38-2	Phosphoric Acid	2	x						

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7664-41-7	Ammonia	2	x						
7664-93-9	Sulfuric Acid	2	x						
7697-37-2	Nitric Acid	2	x						
7723-14-0	Phosphorus	2	x						
7738-94-5	Chromic(VI) Acid	2							
7757-82-6	Sodium Sulfate	2							
7758-01-2	Potassium Bromate	2							
7758-97-6	Lead Chromate	2	x						
7782-49-2C	Selenium & Selenium Compounds (other than Hydrogen Selenide)	2	x						
7783-06-4	Hydrogen Sulfide	2	x						
7783-07-5	Hydrogen Selenide	2	x						
7783-20-2	Ammonium sulfate	2							
7803-63-6	Ammonium bisulfate	2							
106-88-7	1,2-Epoxybutane	3	x						
108-05-4	Acetic acid vinyl ester	3	x				x	x	
108-39-4	3-Methylphenol	3	x		x		x	x	
111-76-2	2-Butoxyethanol	3	x				x	x	
117-81-7	Di(2-ethylhexyl)phthalate	3	x				x	x	
156-60-5	Trans-1,2-dichloroethene	3		x	x			x	
1634-04-4	Methyl Tertiary Butyl Ether	3	x					x	
1836-75-5	Nitrofen	3	x						
189-55-9	Dibenzo[a,i]pyrene	3	x						
189-64-0	Dibenzo[a,h]pyrene	3	x						
191-30-0	Dibenzo[a,l]pyrene	3	x						
192-65-4	Dibenzo[a,e]pyrene	3	x		x				
193-39-5	Indeno[1,2,3-cd]pyrene	3	x		x			x	
205-82-3	Benzo[j]fluoranthene	3	x					x	
205-99-2	Benzo[b]fluoranthene	3	x		x			x	

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207-08-9	Benzo[k]fluoranthene	3	x		x			x	
218-01-9	Chrysene	3		x	x			x	
224-42-0	Dibenz[a,j]acridine	3	x						
226-36-8	Dibenz[a,h]acridine	3	x						
2385-85-5	Mirex	3	x						
3697-24-3	5-Methylchrysene	3	x						
50-00-0	Formaldehyde	3	x						
50-29-3	DDT	3	x		x				
56-49-5	3-Methylcholanthrene	3		x	x				
56-55-3	Benz[a]anthracene	3	x		x				x
59-89-2	n-Nitrosomorpholine	3	x		x		x		
602-87-9	5-Nitroacenaphthene	3	x						
60-35-5	Acetamide	3	x						
621-64-7	n-Nitrosodi-n-propylamine	3	x		x		x		x
630-20-6	1,1,1,2-Tetrachloroethane	3		x	x				x
67-72-1	Hexachloroethane	3	x		x		x		
72-54-8	DDD	3		x	x				
72-55-9	DDE	3		x	x				
75-07-0	Acetaldehyde	3	x						
75-27-4	Bromodichloromethane	3		x	x				x
88-06-2	2,4,6-Trichlorophenol	3	x		x		x		
91-20-3	Naphthalene	3	x		x		x		x
95-48-7	2-Methylphenol	3	x		x		x		x
110-80-5	2-Ethoxyethanol	4	x		x		x	x	
121-14-2	2,4-Dinitrotoluene	4	x		x		x	x	
79-46-9	2-Nitropropane	4	x		x		x		
10595-95-6	n-Nitroso-n-methylethylamine	5	x		x	x			
10102-44-0	Nitrogen dioxide [c]	6				x		x	
593-74-8	Dimethyl Mercury	6				x			

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630-08-0	Carbon monoxide [c]	6				x			
100-42-5	Styrene	7	x					x	
98-82-8	Cumene	8	x						x
10028-15-6	Ozone	9							
7446-09-5	Sulfur dioxide	9							
7647-01-0	Hydrogen chloride	10	x						
7664-39-3	Hydrogen Fluoride	10	x						
7782-41-4	Fluorine gas F2	10	x						
7782-50-5	Chlorine	10	x						
1746-01-6	2,3,7,8-Tetrachlorodibenzo-p-dioxin	11	x					x	
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	11						x	
31508-00-6	2,3',4,4',5-Pentachlorobiphenyl	11						x	
32598-13-3	3,3',4,4'-Tetrachlorobiphenyl	11						x	
32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl	11						x	
3268-87-9	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-Dioxin	11			x			x	
32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl	11						x	
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	11			x			x	
38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl	11						x	
39001-02-0	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	11			x			x	
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	11						x	
39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl	11						x	
40321-76-4	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	11						x	
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran	11							x
52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl	11							x
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran	11			x				x
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	11							x
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran	11							x
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran	11							x

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57465-28-8	3,3',4,4',5-Pentachlorobiphenyl	11							x
57653-85-7	1,2,3,6,7,8 Hexachlorodibenzo-p-dioxin	11							x
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran	11							x
65510-44-3	2',3,4,4',5-Pentachlorobiphenyl	11							x
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran	11			x				x
69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl	11							x
70362-50-4	3,4,4',5-Tetrachlorobiphenyl	11							x
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	11							x
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran	11							x
74472-37-0	2,3,4,4',5-Pentachlorobiphenyl	11							x
34465-46-8	Hexachlorodibenzo-p-Dioxins, NOS	12							
37871-00-4	Heptachlorodibenzo-p-dioxins, NOS	12							
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin & Related Compounds, NOS	12		x					
100-44-7	Benzyl Chloride	13	x					x	
101-77-9	4,4'-Methylenedianiline	13	x					x	
103-33-3	Azobenzene	13						x	
106-44-5	4-Methylphenol	13		x	x			x	
106-89-8	Epichlorohydrin	13	x					x	
107-21-1	Ethylene Glycol	13	x					x	
107-98-2	Propylene glycol monomethyl ether	13	x					x	
109-86-4	2-Methoxyethanol	13	x					x	
111-15-9	Ethylene glycol monoethyl ether acetate	13	x					x	
111-44-4	Bis(chloroethyl)ether	13	x		x			x	
1120-71-4	1,3-Propane Sultone	13	x					x	
122-66-7	1,2-Diphenylhydrazine	13	x		x			x	
124-48-1	Dibromochloromethane	13		x	x			x	
133-06-2	Captan	13	x					x	

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510-15-6	Chlorobenzilate	13	x		x				
51-79-6	Ethyl Carbamate	13	x						
532-27-4	2-Chloroacetophenone	13	x						
540-73-8	1,2-Dimethylhydrazine	13	x						
542-75-6	1,3-Dichloropropene	13	x						
542-88-1	Bis(chloromethyl)ether	13	x						
57-74-9	Chlordane	13	x		x				
584-84-9	Toluene-2,4-diisocyanate	13	x						
593-60-2	Vinyl Bromide	13	x						
60-11-7	4-Dimethylaminoazobenzene	13	x		x				
62-53-3	Aniline	13	x		x				
75-25-2	Bromoform	13	x		x				x
75-44-5	Phosgene	13	x						
77-47-4	Hexachlorocyclopentadiene	13	x		x				
822-06-0	1,6-Hexamethylene diisocyanate	13	x						
85-44-9	Phthalic Anhydride	13	x		x				
90-04-0	o-Anisidine	13	x		x				
91-94-1	3,3'-Dichlorobenzidine	13	x						
924-16-3	n-Nitroso-di-n-butylamine	13	x		x				
94-59-7	Safrole	13		x	x				
95-53-4	o-Toluidine	13	x						
96-12-8	1,2-Dibromo-3-chloropropane	13	x		x				x
96-18-4	1,2,3-Trichloropropane	13	x		x				
96-45-7	Ethylene Thiourea	13	x						
80-62-6	Methyl methacrylate	14	x		x				x
10034-93-2	Hydrazine Sulfate	15							
10048-13-2	Sterigmatocystin	15							
100-75-4	n-Nitrosopiperidine	15		x	x				
101-14-4	4,4-Methylene bis(2-chloroaniline)	15	x		x				

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101-61-1	4,4'-Methylene bis(n,n'-dimethyl)aniline	15							
101-68-8	Methylene diphenyl isocyanate	15	x						
101-80-4	4,4'-Diaminodiphenyl Ether	15	x						
101-90-6	Diglycidyl Resorcinol Ether	15	x						
1024-57-3	Heptachlor epoxide	15		x	x				
107-30-2	Chloromethyl methyl ether	15	x						
108171-26-2	Chlorinated Paraffins	15							
108-31-6	Maleic Anhydride	15	x						
110-49-6	Ethylene glycol monomethyl ether acetate	15	x						
111-30-8	Glutaraldehyde	15	x						
111-42-2	Diethanolamine	15	x						
1116-54-7	n-Nitrosodiethanolamine	15							
115-02-6	Azaserine	15							
115-07-1	Propylene	15							
115-28-6	Chlorendic Acid	15							
117-10-2	Dantron	15							
117-79-3	2-Aminoanthraquinone	15	x						
120-71-8	para-Cresidine	15			x				
126-72-7	Tris(2,3-dibromopropyl)phosphate	15		x	x				
129-15-7	2-Methyl-1-nitroanthraquinone	15	x						
132-27-4	o-Phenylphenate, Sodium	15							
1332-21-4	Asbestos	15	x						
1335-32-6	Lead Subacetate	15							
134-29-2	o-Anisidine Hydrochloride	15							
135-20-6	Cupferron	15	x						
13552-44-8	4,4-Methylenedianiline Dihydrochloride	15	x						
136-40-3	Phenazopyridine hydrochloride	15							
139-13-9	Nitrilotriacetic acid	15							
139-65-1	4,4-Thiodianiline	15	x						

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140-57-8	Aramite	15		x	x				
143-50-0	Chlordecone	15		x	x				
148-82-3	Melphalan	15							
151-56-4	Ethyleneimine	15	x						
156-10-5	p-Nitrosodiphenylamine	15							
1596-84-5	Alar	15							
16071-86-6	Direct Brown 95	15							
16543-55-8	n-Nitrosonornicotine	15							
16568-02-8	Gyromitrin	15							
1694-09-3	Benzyl Violet 4B	15	x						
18662-53-8	Nitrilotriacetic acid, trisodium salt monohydrate	15							
18883-66-4	Streptozotocin	15							
1897-45-6	Chlorothalonil	15							
1937-37-7	Direct Black 38	15							
194-59-2	7h-Dibenzo[c,g]carbazole	15							
2425-06-1	Captafol	15	x						
2475-45-8	Disperse Blue 1	15							
25013-16-5	Butylated hydroxyanisole	15							
2602-46-2	Direct Blue 6	15							
26148-68-5	A-alpha-c(2-amino-9h-pyrido[2,3-b]indole)	15							
26471-62-5	Toluene-diisocyanates	15							
2784-94-3	HC Blue 1	15							
298-04-4	Disulfoton	15	x		x				
301-04-2	Lead Acetate	15	x						
302-01-2	Hydrazine	15	x						
303-34-4	Lasiocarpine	15							
305-03-3	Chlorambucil	15							

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3068-88-0	beta-Butyrolactone	15	x						
315-22-0	Monocrotaline	15							
3223-07-2	Melphalan HCl	15							
32534-81-9	Pentabromodiphenyl Ether	15							
333-41-5	Diazinon	15	x						
3546-10-9	Phenesterin	15							
3564-09-8	Ponceau 3R	15							
3570-75-0	Nifurthiazole	15							
366-70-1	Procarbazine Hydrochloride	15							
3688-53-7	Furylfuramide	15							
3761-53-3	Ponceau MX	15	x						
39156-41-7	2,4-Diaminoanisole Sulfate	15							
40088-47-9	Tetrabromodiphenyl Ether	15							
42397-64-8	1,6-Dinitropyrene	15							
42397-65-9	1,8-Dinitropyrene	15							
4342--03-4	Dacarbazine	15							
446-86-6	Azathioprine	15							
492-80-8	Auramine	15							
50-06-6	Phenobarbital	15							
50-07-7	Mitomycin C	15							
50-18-0	Cyclophosphamide (anhydrous)	15							
50-28-2	Estradiol 17b	15							
50-55-5	Reserpine	15							
505-60-2	Sulfur Mustard	15							
50-76-0	Actinomycin D	15							
513-37-1	Dimethylvinylchloride	15							
51-52-5	Propylthiouracil	15							
5160-02-1	D & C Red No. 9	15							
52-24-4	Tris-(1-Aziridinyl)phosphine sulfide	15							

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531-82-8	n-[4-(5-nitro-2-furyl)-2-thiazolyl]-acetamide	15	x						
53-96-3	2-Acetylaminofluorene	15	x		x				
54749-90-5	Chlorozotocin	15							
55-18-5	n-Nitrosodiethylamine	15	x		x				
5522-43-0	1-Nitropyrene	15							
555-84-0	1-[(5-Nitrofurfurylidene)-amino]-2-imidazolidinone	15							
55738-54-0	Trans-2[(dimethylamino)-methylimino]-5-[2-(5-nitro-2-furyl)-vinyl]-1,3,4-oxadiazole	15	x						
56-04-2	Methylthiouracil	15							
563-47-3	3-Chloro-2-methyl-propene	15							
56-53-1	Diethylstilbestrol	15							
569-61-9	C.I. Basic Red 9 Monohydrochloride	15							
57-55-6	Propylene Glycol	15							
57-57-8	beta-Propiolactone	15	x						
57835-92-4	4-Nitropyrene	15							
57-97-6	7,12-Dimethylbenz[a]anthracene	15							
59-87-0	Nitrofurazone	15	x						
59-96-1	Phenoxybenzamine	15							
6055-19-2	Cyclophosphamide (Hydrated)	15							
60568-05-0	Furmecyclox	15							
607-57-8	2-Nitrofluorene	15							
608-73-1	Hexachlorocyclohexane	15							
6109-97-3	3-Amino-9-ethylcarbazole hydrochloride	15							
615-05-4	2,4-Diaminoanisole	15							
615-53-2	n-Nitroso-n-Methylurethane	15	x						
61-82-5	Amitrole	15	x						
62-44-2	Phenacetin	15		x	x				

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62450-06-0	Tryptophan-P-1	15							
62450-07-1	Tryptophan-P-2	15							
62-55-5	Thioacetamide	15							
62-56-6	Thiourea	15							
62-73-7	Dichlorvos	15	x						
627-44-1	Diethyl mercury	15							
636-21-5	o-Toluidine Hydrochloride	15	x						
63-92-3	Phenoxybenzamine hydrochloride	15	x						
6423-43-4	Propylene Glycol Dinitrate	15	x						
66-27-3	Methyl Methanesulfonate	15		x	x				
671-16-9	Procarbazine	15							
67730-10-3	Glu-P-2	15							
67730-11-4	Glu-P-1	15							
68006-83-7	2-Amino-3-methyl-9H pyrido[2,3-b]indole	15							
68-12-2	n,n-Dimethylformamide	15	x						
684-93-5	n-Nitroso-n-methylurea	15	x						
70-25-7	n-Methyl-n-nitro-n-nitrosoguanidine	15							
712-68-5	2-Amino-5-(5-Nitro-2-Furyl)-1,3,4-Thiadiazol	15							
7440-02-0RD	Nickel Refinery Dust	15							
74-90-8	Hydrogen Cyanide	15	x						
7496-02-8	6-Nitrochrysene	15							
75-37-6	1,1-Difluoroethane	15							
75-56-9	Propylene oxide	15	x						
75-68-3	1-Chloro-1,1-difluoroethane	15							
759-73-9	n-Nitroso-n-ethylurea	15	x						
76-06-2	Chloropicrin	15	x						
76180-96-6	2-Amino-3-methylimidazo-[4,5-f]quinoline	15							
7631-86-9	Silica (crystalline, Respirable)	15							
7784-42-1	Arsine	15	x						

Table C-1 Updated List of Toxic Air Pollutants (395 constituents)

CAS #	Constituent	Disp-osition [a]	Old TAP Input to RDQO Table A-1 [b]	Other Inputs to RDQO Table A-1 [c]	Updates to RDQO Input List Table A-4 [d]	Compare w/ CHG Vapor Study List Table B-1 [e]	Compare w/ TWINS/BBI List Table A-4 [f]	Compare w/ EPA PICs Table E-1 [g]	Compare w/ Site-Specific PICs Table F-1 [h]
7803-51-2	Phosphine	15	x						
78-59-1	Isophorone	15	x						
79-06-1	Acrylamide	15	x		x				
79-44-7	Dimethylcarbamoyl Chloride	15	x						
8007-45-2	Coke Oven Emissions	15							
811-97-2	1,1,1,2-Tetrafluoroethane	15							
82-28-0	1-Amino-2-methylanthraquinone	15							
838-88-0	4,4-Methylene bis(2-Methylaniline)	15	x						
85535-84-8	Short-chain (C10-13) chlorinated paraffins	15							
86-30-6	n-Nitrosodiphenylamine	15	x		x				
87-29-6	Cinnamyl Anthranilate	15							
90-94-8	Michler's ketone	15							
91-08-7	Toluene-2,6-diisocyanate	15							
91-59-8	2-Naphthylamine	15		x	x				
92-67-1	4-Aminobiphenyl	15	x		x				
92-87-5	Benzidine	15	x						
930-55-2	n-Nitrosopyrrolidine	15		x	x				
94-58-6	Dihydrosafrole	15							
94-78-0	Phenazopyridine	15							
95-06-7	Sulfallate	15							
95-69-2	p-Chloro-o-toluidine	15							
95-80-7	2,4-Diaminotoluene	15	x						
95-83-0	4-Chloro-o-phenylenediamine	15							
96-09-3	Styrene Oxide	15	x						
97-56-3	ortho-Aminoazotoluene	15	x						
99-59-2	5-Nitro-o-Anisidine	15							
DEEP	Diesel Engine Exhaust, Particulate	15							
NA22	Refractory Ceramic Fibers	15	x						
PBBs	Polybrominated Biphenyls	15							

Table C-1 Updated List of Toxic Air Pollutants (395 constituents)

CAS #	Constituent	Disp-osition [a]	Old TAP Input to RDQO Table A-1 [b]	Other Inputs to RDQO Table A-1 [c]	Updates to RDQO Input List Table A-4 [d]	Compare w/ CHG Vapor Study List Table B-1 [e]	Compare w/ TWINS/BBI List Table A-4 [f]	Compare w/ EPA PICs Table E-1 [g]	Compare w/ Site-Specific PICs Table F-1 [h]

Notes:

[a] Disposition Codes:

1 RDQO COPCs; the new TAPS review resulted in no changes to the previous COPC feed list (Appendix A, Table A-2).

2 Inorganic compounds addressed as individual cations or anions in the tank liquid; no additions to the previous COPC inorganic feed list (Appendix A, Table A-5).

3 Low toxicity compounds; the new TAPS review resulted in no changes to the previous COPC list (Appendix A, Table A-3).

4 Updates to the RDQO Input List (e.g. UHCs); no changes to the Appendix A, Table A-4 additions.

5 Organic identified by CHG as present in tank vapor space; no changes to the Appendix B, Table B-1 additions.

6 Inorganics identified by CHG as present in tank vapor space; no changes to the Appendix B, Table B-1 additions.

7 Regulatory basis for this RDQO COPC was removed in the evaluation of the UHC/UTS, DST Part A updates (Appendix A, Table A-4); the TAPS update review provides the new regulatory basis.

8 Reglatory basis for this low-toxicity compound was removed in the evaluation of the UHC/UTS, DST Part A updates (Appendix A, Table A-4); the TAPS update review provides the new regulatory basis.

9 Toxic air pollutant to be measured in stack emissions; identified by EPA as a Criteria Pollutant (40 CFR 60)

10 Inorganics be measured in stack emissions at the request of Ecology.

11 Chlorinated dioxins, furans and related coplanar PCBs to be measured in stack emissions; compounds are identified by EPA as PICs (Appendix E)

12 Chlorinated dioxins and related compounds NOS will not be added to the stack emissions measurement.

13 Eliminated as feed constituents because they have < 10 detects in TWINS and no BBI values were found; appear on the EPA PIC list (Appendix E).

14 Eliminated as feed constituents because they have < 10 detects in TWINS and no BBI values were found; appear on the site-specific PIC list (Appendix F).

15 Eliminated because they have < 10 detects in TWINS and no BBI values were found.

[b] An “X” in the box indicates that the toxic air pollutant was identified in WAC 173-460 prior to the May 2009 revision and was evaluated as an input to the RDQO.
[c] An “X” in the box indicates that the toxic air pollutant was identified as another input to the RDQO (UTS/UHC, DST Part A, flammable gas); see Appendix A, Table A-1.
[d] An “X” in the box indicates that the toxic air pollutant was identified in the updates to UTS/UHC and DST Part A constituent lists; see Appendix A, Table A-4
[e] An “X” in the box indicates that the toxic air pollutant was identified in the CHG vapor study; see Appendix B, Table B-1
[f] Compounds with more than 10 detects in TWINS or listed in BBI; identified with an “X”.
[g] Compounds identified by an "X" are listed by EPA as a PIC, see Appendix E, Table E-1.
[h] Compounds identified by an "X" are listed by WTP as a site-specific PIC, see Appendix F, Table F-1.

Table C-2 Original List of Toxic Air Pollutants (669 constituents)

CAS#	Constituent	Former Class A or B TAP and Retained by WAC Update[a]	Class A or B TAPs that Appear on Other RDQO Input Lists[b]	RDQO Input Update List [c]	TWINS / BBI [d]
100-42-5	Styrene	x			
106-46-7	1,4-Dichlorobenzene	x	x	x	x
106-93-4	Ethylene dibromide	x	x	x	
106-99-0	1,3-Butadiene	x			
107-02-8	Acrolein	x	x	x	
107-05-1	3-Chloropropene	x	x	x	
107-06-2	1,2-Dichloroethane	x	x	x	x
107-13-1	Acrylonitrile	x	x	x	
108-10-1	4-Methyl-2-pentanone	x	x	x	x
108-88-3	Toluene	x	x	x	x
108-90-7	Chlorobenzene	x	x	x	x
108-95-2	Phenol	x	x	x	x
110-54-3	n-Hexane	x			
110-82-7	Cyclohexane	x			
118-74-1	Hexachlorobenzene	x	x	x	
121-44-8	Triethylamine	x	x	x	
123-91-1	1,4-Dioxan	x	x	x	
127-18-4	1,1,2,2-Tetrachloroethene	x	x	x	x
1336-36-3	Polychlorinated biphenyls (PCBs)	x	x	x	x
309-00-2	Aldrin	x	x	x	
319-84-6	alpha-BHC	x	x	x	
319-85-7	beta-BHC	x	x	x	
50-32-8	Benzo(a)pyrene	x	x	x	
53-70-3	Dibenz[a,h]anthracene	x	x	x	
56-23-5	Carbon tetrachloride	x	x	x	x
57-14-7	1,1-Dimethylhydrazine	x			
58-89-9	gamma-BHC (Lindane)	x	x	x	

Table C-2 Original List of Toxic Air Pollutants (669 constituents)

CAS#	Constituent	Former Class A or B TAP and Retained by WAC Update[a]	Class A or B TAPs that Appear on Other RDQO Input Lists[b]	RDQO Input Update List [c]	TWINS / BBI [d]
60-57-1	Dieldrin	x	x	x	
624-83-9	Methyl isocyanate	x			
62-75-9	N-Nitroso-N,N-dimethylamine	x	x	x	
67-56-1	Methyl alcohol	x	x	x	
67-63-0	2-Propyl alcohol	x			
67-66-3	Chloroform	x	x	x	x
71-43-2	Benzene	x	x	x	x
71-55-6	1,1,1-Trichloroethane	x	x	x	x
74-83-9	Bromomethane	x	x	x	
74-87-3	Chloromethane	x	x	x	x
75-00-3	Chloroethane	x	x	x	
75-01-4	1-Chloroethene	x	x	x	x
75-05-8	Acetonitrile	x	x	x	
75-09-2	Dichloromethane (Methylene Chloride)	x	x	x	x
75-15-0	Carbon disulfide	x	x	x	x
75-21-8	Oxirane	x	x	x	
75-34-3	1,1-Dichloroethane	x	x	x	
75-35-4	1,1-Dichloroethene	x	x	x	x
75-45-6	Chlorodifluoromethane	x			
76-44-8	Heptachlor	x	x	x	
78-87-5	1,2-Dichloropropane	x	x	x	
78-93-3	2-Butanone	x	x	x	x
79-00-5	1,1,2-Trichloroethane	x	x	x	x
79-01-6	1,1,2-Trichloroethylene	x	x	x	x
79-10-7	2-Propenoic acid	x			
79-34-5	1,1,2,2-Tetrachloroethane	x	x	x	x
8001-35-2	Toxaphene	x	x	x	
87-68-3	Hexachlorobutadiene	x	x	x	x
87-86-5	Pentachlorophenol	x	x	x	x

Table C-2 Original List of Toxic Air Pollutants (669 constituents)

CAS#	Constituent	Former Class A or B TAP and Retained by WAC Update[a]	Class A or B TAPs that Appear on Other RDQO Input Lists[b]	RDQO Input Update List [c]	TWINS / BBI [d]
16984-48-8	Fluoride	x	x	x	
18540-29-9	Chromium, hexavalent metal and compounds [f]	x			
7440-43-9	Cadmium	x	x	x	
7664-41-7	Ammonia	x	x		
7697-37-2	Nitric acid/Nitrate	x	x		
7723-14-0	Phosphorus	x			
106-88-7	1,2-Epoxybutane	x			
108-05-4	Acetic acid vinyl ester	x			x
108-39-4	m-Cresol	x	x	x	x
111-76-2	2-Butoxyethanol	x			x
117-81-7	Bis(2-ethylhexyl) phthalate	x	x		x
1634-04-4	Methyl tert-butyl ether	x			
1836-75-5	Nitrofen	x			
189-55-9	Dibenzo[a,i]pyrene	x			
189-64-0	Dibenzo[a,h]pyrene	x			
191-30-0	Dibenzo(a,l)pyrene	x			
192-65-4	Dibenzo[a,e]pyrene	x	x	x	
193-39-5	Indeno(1,2,3-cd)pyrene	x	x	x	
205-82-3	Benzo[j]fluoranthene	x			
205-99-2	Benzo(b)fluoranthene	x	x	x	
207-08-9	Benzo(k)fluoranthene	x	x	x	
224-42-0	Dibenz[a,j]acridine	x			
226-36-8	Dibenz[a,h]acridine	x			
2385-85-5	Mirex	x			
3697-24-3	5-Methylchrysene	x			
50-00-0	Formaldehyde	x			
50-29-3	4,4-DDT	x	x	x	
56-55-3	Benzo(a)anthracene	x	x	x	
59-89-2	N-Nitrosomorpholine	x	x	x	x

Table C-2 Original List of Toxic Air Pollutants (669 constituents)

CAS#	Constituent	Former Class A or B TAP and Retained by WAC Update[a]	Class A or B TAPs that Appear on Other RDQO Input Lists[b]	RDQO Input Update List [c]	TWINS / BBI [d]
602-87-9	5-Nitroacenaphthene	x			
60-35-5	Acetamide	x			
621-64-7	N-Nitroso-di-n-propylamine	x	x	x	x
67-72-1	Hexachloroethane	x	x	x	x
75-07-0	Acetaldehyde	x			
88-06-2	2,4,6-Trichlorophenol	x	x	x	x
91-20-3	Naphthalene	x	x	x	x
95-48-7	o-Cresol	x	x	x	x
98-82-8	Cumene [f]	x			
10595-95-6	N-Nitrosomethylethylamine	x	x	x	
79-46-9	2-Nitropropane	x		x	x
110-80-5	2-Ethoxyethanol	x	x	x	x
121-14-2	2,4-Dinitrotoluene	x	x	x	x
111-44-4	Bis(2-chloroethyl) ether	x	x	x	
75-25-2	Tribromomethane	x	x	x	
77-47-4	Hexachlorocyclopentadiene	x	x	x	
78-59-1	Isophorone	x			
86-30-6	N-Nitrosodiphenylamine	x	x	x	
91-94-1	3,3 -Dichlorobenzidine	x			
100-44-7	Benzyl chloride	x			
10049-04-4	Chlorine dioxide	x			
101-14-4	4,4'-Methylenebis(2-chloroaniline)	x	x	x	
101-68-8	Methylene bis(phenyl isocyanate)	x			
101-77-9	4,4-Methylene dianiline	x			
101-80-4	4,4'-Diaminodiphenyl ether	x			
101-90-6	Diglycidyl resorcinol ether	x	x		
106-89-8	Epichlorohydrin	x			
107-21-1	Ethylene glycol	x			
107-30-2	Chloromethyl methyl ether	x			

Table C-2 Original List of Toxic Air Pollutants (669 constituents)

CAS#	Constituent	Former Class A or B TAP and Retained by WAC Update[a]	Class A or B TAPs that Appear on Other RDQO Input Lists[b]	RDQO Input Update List [c]	TWINS / BBI [d]
107-98-2	Propylene glycol monomethyl ether	x			
108-31-6	Maleic anhydride (2,5-Furandione)	x			
109-86-4	2-Methoxyethanol	x			
110-49-6	2-Methoxyethyl acetate	x			
111-15-9	2-Ethoxyethyl acetate	x			
111-30-8	Glutaraldehyde	x			
111-42-2	Diethanolamine	x			
1120-71-4	1,3-Propane sultone	x			
117-79-3	2-Aminoanthraquinone	x			
122-66-7	1,2-Diphenylhydrazine	x	x	x	
129-15-7	2-Methyl-1-nitroanthraquinone	x			
1309-64-4	Antimony trioxide, as Sb	x			
1310-73-2	Sodium hydroxide	x	x		
1314-62-1	Vanadium pentoxide	x	x		
133-06-2	Captan	x			
1332-21-4	Asbestos (fiberous)	x			
135-20-6	Cupferron	x			
13552-44-8	4,4-Methylenedianiline dihydrochloride	x			
139-65-1	4,4'-Thiodianiline	x	x		
151-56-4	Ethyleneimine	x			
1694-09-3	Benzyl violet 4b	x			
1746-01-6	TCDD (Dioxin/Furan Indicator)	x	x		
2425-06-1	Captafol	x			
298-04-4	Disulfoton	x	x	x	
301-04-2	Lead acetate	x			
302-01-2	Hydrazine	x			
3068-88-0	B-Butyrolactone	x			
333-41-5	Diazinon	x			
3761-53-3	Ponceau MX	x			

Table C-2 Original List of Toxic Air Pollutants (669 constituents)

CAS#	Constituent	Former Class A or B TAP and Retained by WAC Update[a]	Class A or B TAPs that Appear on Other RDQO Input Lists[b]	RDQO Input Update List [c]	TWINS / BBI [d]
510-15-6	Chlorobenzilate	x	x	x	
51-79-6	Ethyl carbamate (urethane)	x			
531-82-8	N-(4-(5-Nitro-2-furyl)-2-thiazolyl)acetamide	x			
532-27-4	a-Chloroacetophenone	x			
53-96-3	2-Acetylaminofluorene	x	x	x	
540-73-8	1,2-Dimethylhydrazine	x			
542-75-6	1,3-Dichloropropene	x			
542-88-1	Dichloromethyl ether	x			
55-18-5	N-Nitrosodiethylamine	x	x	x	
55738-54-0	trans-2((Dimethylamino)methylimino)-5-(2-(5-nitro-2-furyl) vinyl-1,3,4-oxadiazole	x			
57-57-8	B-Propiolactone	x			
57-74-9	Chlordane	x	x	x	
584-84-9	2,4-Toluene diisocyanate	x			
593-60-2	Vinyl bromide	x			
59-87-0	Nitrofurazone	x			
60-11-7	p-Dimethylaminoazobenzene	x	x	x	
615-53-2	N-Nitroso-N-methylurethane	x			
61-82-5	Amitrole	x			
62-53-3	Aniline	x	x	x	
62-73-7	Dichlorvas	x			
636-21-5	o-Toluidine hydrochloride	x			
63-92-3	Phenoxybenzamine hydrochloride	x			
6423-43-4	Propylene glycol dinitrate	x			
68-12-2	Dimethylformamide	x			
684-93-5	N-Nitroso-N-methylurea	x			
7439-92-1D	Lead compounds	x			
7439-96-5Ca	Manganese dust & compounds	x			
7440-38-2C	Arsenic and inorganic arsenic compounds	x			